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## Laparoscopic surgery for benign and malign diseases of the digestive system: Indications, limitations, and evidence

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### Abstract

The laparoscopic technique was introduced in gastrointestinal surgery in the mid 1980s. Since then, the development of this technique has been extraordinary. Triggered by technical innovations (stapling devices or coagulation/dissecting devices), nowadays any type of gastrointestinal resection has been successfully performed laparoscopically and can be performed laparoscopically dependent on the patient's condition. This summary gives an overview over 30 years of laparoscopic surgery with focus on today's indications and evidence. Main indications remain the more common procedures, *e.g.*, appendectomy, cholecystectomy, bariatric procedures or colorectal resections. For all these indications, the laparoscopic approach has become the gold standard with less perioperative morbidity. Regarding oncological outcome there have been several high-quality randomized controlled trials which demonstrated equivalency between laparoscopic and open colorectal resections. Less common procedures like esophagectomy, oncological gastrectomy, liver and pancreatic resections can be performed successfully as well by an

experienced surgeon. However, the evidence for these special indications is poor and a general recommendation cannot be given. In conclusion, laparoscopic surgery has revolutionized the field of gastrointestinal surgery by reducing perioperative morbidity without disregarding surgical principles especially in oncological surgery.

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**Key words:** Laparoscopy; Gastrointestinal surgery; Esophagus; Stomach; Cholecystectomy, Colorectal surgery; Liver resection; Pancreas resection; Laparoscopic resection of gastrointestinal

**Core tip:** Laparoscopy is known for more than 100 years. In the last three decades there have been significant innovations in laparoscopic surgery that have revolutionized the field of digestive surgery so that by now every surgical procedure for any benign or malign digestive disease has been performed laparoscopically. This article gives an overview over the development of laparoscopic surgery as well as presents the most recent evidence for laparoscopic surgery with special focus on morbidity and equivalency regarding oncological results compared to the open approach.

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### INTRODUCTION

Laparoscopy is known for more than 100 years. The Swedish internist Hans Christian Jacobaeus performed

the first laparoscopy in a human being in 1910<sup>[1]</sup>. Over the following decades, laparoscopy became an important diagnostic tool in the field of internal medicine until non-invasive imaging techniques like sonography or computed tomography (CT) scans developed rapidly. And despite of the visionary potential of the diagnostic and therapeutic use of laparoscopy it took more than 70 years until the first laparoscopic intervention was performed. Again, it was not a general surgeon but the German gynecologist Semm<sup>[2]</sup> who performed the first laparoscopic appendectomy in 1982. While most surgeons took little notice, the German surgeon Erich Mühe was fascinated by this new technique and developed the idea to remove gallstones via laparoscopy in the following years. However, his motives were also the fear of losing parts of surgical competence to other specialties<sup>[3]</sup>. Therefore he developed the “Galloscope” and performed the first laparoscopic cholecystectomy on September 12<sup>th</sup> in 1985 in the Community Hospital in Böblingen, Germany<sup>[4]</sup>.

Initially, there was a strong opposition for this new technique in the surgical community but the success in the following years was overwhelming. It only took about ten years until any gastrointestinal operation was performed laparoscopically although the initial results were not always promising due to limitations in technical aspects and instruments. However, in the past three decades the field of laparoscopic gastrointestinal surgery was one of the most highly developing fields in surgery. Supported by the industrial lobby, surgeons developed new instruments and devices to overcome surgical challenges like bleeding control or gastrointestinal resections. Especially the development of stapling devices for the laparoscopic use and the evolution of coagulation techniques by ultrasound or bipolar coagulation revolutionized the laparoscopic gastrointestinal surgery.

Until now, every gastrointestinal resection has been performed through laparoscopy and there is no intraabdominal organ which cannot be approached laparoscopically. Therefore it is not surprising that the further development of the laparoscopic surgical technique focuses rather on technical details than on medical indications. Besides the introduction of High-Definition or 3D optical systems, the further minimization or even the complete avoidance of surgical accesses by accessing through natural orifices natural orifice transluminal endoscopic surgery are hot topics at the present time. In the future there will be assisting systems based on robotic platforms combined with intraoperative navigation systems which shall reduce one of the biggest disadvantages of laparoscopic gastrointestinal surgery namely the missing tactile perception by more precise preoperative imaging which can be used for intraoperative navigation.

This summary gives an overview over the development as well as today's indications and limitations of laparoscopic surgery with main focus on high-quality evidence regarding perioperative morbidity and especially oncological outcome for the single intraabdominal organ systems.

## GENERAL CONSIDERATIONS

### **Advantages of laparoscopic gastrointestinal surgery**

Minimally invasive abdominal (laparoscopic) surgery shows some significant advantages over open abdominal surgery. It has been proven, that the patient's recovery is significantly shorter after laparoscopic surgery than after open surgery<sup>[5-8]</sup>. In general, surgeries performed laparoscopically have a lower surgical trauma, less blood loss and less postoperative pain and a reduced incisional hernia rate. The pulmonary function is better, the times until the first bowel movement, full recovery and return to work are shorter and finally the patients report a better cosmetic result due to smaller incisions.

### **Disadvantages of laparoscopic gastrointestinal surgery**

On the other hand, laparoscopic gastrointestinal surgery has some major disadvantages compared to open surgery. First of all and evaluated most critically is the missing haptic perception, a surgical tool which is of major relevance in some fields of gastrointestinal surgery. Especially the exploration of the abdominal cavity in patients with malignant diseases is compromised as liver or small bowel cannot be palpated during laparoscopy. In elective patients, an exact (and extended, *e.g.*, intraoperative laparoscopic ultrasound of the liver) staging is necessary to avoid missing out on metastases. Secondly, another disadvantage is the limited field of vision and the handling of intraoperative complications (especially bleeding) which is more difficult in laparoscopic than in open surgery due to the limited intraabdominal space. Another disadvantage—especially in the context of the present discussion about economic aspects of medical treatment—is the fact that the procedural costs of laparoscopic surgery are higher compared to open abdominal surgery<sup>[9,10]</sup>.

## UPPER GI TRACT

Laparoscopic upper GI surgery has been performed since the early 1990s, when benign esophageal disorders like gastroesophageal reflux, achalasia or hiatal and/or paraesophageal hernias<sup>[11-15]</sup> as well as any bariatric procedure<sup>[16-18]</sup> became indications for the laparoscopic approach. About 20 years later, today the laparoscopic approach is gold standard for these indications and also most revisions after failed primary surgery are performed laparoscopically. Moreover, in the past few years more and more gastrointestinal resections due to esophageal, esophagogastric junction or gastric malignancies have been performed minimally invasive.

### **Esophagus**

The treatment for esophageal cancer includes thoracoabdominal esophagectomy with the reconstruction through a gastric pull-up and intrathoracic or cervical esophago-gastrostomy. Depending on the preoperative staging a neo-adjuvant therapy should be performed (either radio-chemotherapy or chemotherapy alone).

The first minimally invasive (thoracoscopic) esophagectomy for esophageal cancer was reported by Law *et al*<sup>[19]</sup> in 1997. In the following years there have been several reports from separate centers which performed laparoscopic or combined thoraco-/laparoscopic esophagectomy for esophageal cancer<sup>[20-23]</sup>. However, these reports mainly focused on technical feasibility of this complex procedure. In 2003, Luketich *et al*<sup>[24]</sup> reported the first larger series with 222 patients who underwent minimally invasive esophagectomy (MIE). They performed a thoraco-/laparoscopic esophagectomy with a conversion rate of 7.2%. At first glance the morbidity rate seems high with a major complication rate of 32% and an anastomotic leakage rate of 11.7%. However both rates do not appear increased compared to the open surgical approach. On the other hand, the mortality rate (1.4%) is very low compared to open esophagectomy (8%-22%)<sup>[25]</sup>. In 2012, the authors reported results of over 1000 patients who underwent MIE with similar results. Comparable to open esophagectomy patients with intrathoracic anastomosis (Ivor-Lewis-Esophagectomy) showed lower complication rates than patients with neck anastomosis<sup>[26]</sup>. These results indicate that MIE is feasible with very good perioperative outcomes and they were confirmed by Biere *et al*<sup>[27]</sup> in 2012 when they presented data from a randomized controlled trial (RCT) comparing open and minimally invasive esophagectomy regarding short-term postoperative complications and found benefits in the minimally invasive group especially regarding pulmonary infections. However, the now widely spread use of MIE is limited by the lack of high-quality studies on the oncological outcome comparing open and laparoscopic approach<sup>[28]</sup> as well as a lack of high-quality clinical studies comparing the gold standard (open Ivor-Lewis-Esophagectomy) to MIE<sup>[29]</sup>.

Therefore, due to missing evidence, today's MIE should only be performed by surgeons in specialized centers who are experienced in minimally invasive esophageal surgery.

### Stomach

Laparoscopic gastric resections have been performed since the early 1990s mainly as bariatric procedures. The advantages of laparoscopic surgery are evident especially in critically ill patients and also revolutionized the bariatric surgery. However, laparoscopic gastric surgery in general benefits from the experience of the bariatric surgeon. By now, every type of gastric resection has been performed laparoscopically. However, the evidence for laparoscopic gastric surgery is still poor-except for bariatric surgery which may be the surgical field with the best overall evidence.

It has been proven in many high-quality-studies that bariatric surgery per se is superior to conservative weight reduction programs in morbidly obese patients<sup>[30-33]</sup>. Especially regarding the long-term weight-loss<sup>[30,31]</sup> and the relief of co-morbidities there is no such sufficient therapy like bariatric surgery<sup>[32,33]</sup>. Whether it is better to

perform restrictive procedures like the sleeve gastrectomy, or malabsorptive procedures like the gastric bypass is currently under investigation in good-quality prospective trials<sup>[34]</sup>. However, laparoscopic bariatric surgery is still the most frequently performed laparoscopic surgery in the upper GI tract.

Other indications for laparoscopic gastric resections are benign or malign lesions of the stomach or the esophago-gastric junction. The first report of a laparoscopic distal gastric resection was presented by Goh *et al*<sup>[35]</sup>. In 1995 Uyama *et al*<sup>[36]</sup> first reported a laparoscopic resection of the proximal part of the stomach and the esophago-gastric junction. One year later the first case series of laparoscopic total gastrectomy was reported by Fowler and White<sup>[37]</sup>. In the beginning, laparoscopic gastric resections were performed due to benign diseases, mainly peptic ulcer disease. Later on, the range of indications extended to resections for early gastric cancer<sup>[38-40]</sup>. However, the hope for a renaissance of gastric surgery<sup>[41]</sup> did not last for long, as with the introduction of the proton-pump-inhibitors in the late 1980s and the further development of endoscopic interventions (*e.g.*, endoscopic submucosal dissection or full-thickness-resection-techniques) today most of these diseases can be treated endoscopically. Therefore, beside bariatric surgery, modern gastric surgery is mainly performed due to gastric cancer. Subtotal or total gastrectomy is the surgical procedure of choice. From the technical point of view there are no limitations for the laparoscopic gastrectomy (LG) as it had been proven since the mid 1990s<sup>[37]</sup>. So the remaining question is the analysis of oncological results of the laparoscopic approach compared to the standard open gastrectomy (OG) as surgery is the only curative option in patients with gastric cancer. There are a few meta-analyses of LG *vs* OG for advanced gastric cancer<sup>[42-44]</sup>. Beside the known advantages of laparoscopic surgery (less blood loss, shorter time until first bowel movement, shorter hospital stay and fewer complications) they found no difference regarding oncological parameters: harvested lymph nodes, surgical radicalness, recurrence rates and overall survival were *idem* in the laparoscopic and the open surgery groups. However, all authors state that LG should be performed by experienced minimally invasive surgeons.

There is clear evidence that LG for gastric cancer shows similar oncological results to the OG with fewer surgical complications in the hands of skilled endoscopic surgeons.

## HEPATOPANCREATOBILIARY SYSTEM

As described above, the era of laparoscopic gastrointestinal surgery was started in 1985 by the first laparoscopic cholecystectomy performed by Erich Mühle<sup>[3,4]</sup>. While today the gallbladder is resected laparoscopically in about 95% of the cases, laparoscopic surgery for liver and pancreatic diseases are not that widespread in the surgical community. This might be due to the fact that these types

of operations by far are less common. However, by now it has been demonstrated that nearly any type of hepatopancreatobiliary resection can be performed laparoscopically.

### Liver/gallbladder

Since its introduction in 1985<sup>[4]</sup>, it took only a few years until laparoscopic cholecystectomy became the standard technique for cholecystectomy. Indications were widened over the time and today there are nearly no specific contraindications for laparoscopic cholecystectomy. Initially there were reports of tumor cell seeding and surgical site metastasis in cases of laparoscopic removal of gallbladder carcinomas<sup>[45-47]</sup>. With the introduction of removal bags, these problems were eliminated and today gallbladders with masses of unknown dignity should also be removed laparoscopically.

The first reported laparoscopic liver operation was a laparoscopic drainage of an amebic liver abscess in 1985<sup>[48]</sup>. Several reports of laparoscopic fenestration of symptomatic liver cysts and laparoscopic atypical liver resection followed<sup>[49-56]</sup>, but it was not until 1996 that the first laparoscopic major liver resections were performed<sup>[56,57]</sup>. The disadvantages of laparoscopic surgery (the missing haptic perception and coagulation/dissecting techniques) had to be overcome especially in laparoscopic liver surgery. The development of laparoscopic ultrasound devices, as well as water jet or ultrasonic dissectors and laparoscopic stapling devices, were necessary to take the next step in laparoscopic liver surgery<sup>[58-64]</sup>. In the following decade, every type of major hepatic resection was performed laparoscopically<sup>[65-69]</sup> which had previously been the same indications for open surgery. By now, minor atypical resections as well as left-lateral hepatectomies are performed laparoscopically by default. Extended liver resections like right-sided hepatectomy or even trisegmentectomy should only be performed by an experienced hepatobiliary and laparoscopic surgeon due to the complexity of this procedures. Another indication for laparoscopic liver resection is the living-donor hepatectomy for liver transplantation<sup>[70,71]</sup>, either left-sided hepatectomy or right-sided hepatectomy can be performed.

There is increasing evidence in high-quality meta-analyses that laparoscopic liver resection is equivalent to open liver resection regarding mid-term and long-term oncological outcomes in cases of malignant diseases (primary liver tumors as well as liver metastases). However, the perioperative and short-term advantages of laparoscopic surgery are also present in laparoscopic liver surgery<sup>[72-74]</sup>.

### Pancreas

The first laparoscopic pancreatic resection was reported in 1994 by the Canadian surgeon Michael Gagner, who performed a laparoscopic pylorus-preserving pancreatoduodenectomy in a patient with chronic pancreatitis<sup>[75]</sup>. The complex reconstruction required gastrojejunostomy, hepaticojejunostomy and pancreaticojejunostomy. With a hospital stay of 30 d, Gagner concluded that laparoscopic pancreatic head resection is feasible but the known ad-

vantages of laparoscopic surgery did not seem evident in pancreatic surgery. In the same year, Cuschieri<sup>[76]</sup> reported about his experience with laparoscopic pancreas surgery and came to same conclusion. Interestingly, both authors independently revised their opinion two years later, when after a small series of laparoscopic distal pancreatectomies they concluded that the advantages of laparoscopic surgery (less postoperative pain, shorter hospital-stay, fewer perioperative complications) are also shown in pancreatic surgery, with a restriction to distal pancreatectomies for benign indications (mainly insulinoma or chronic pancreatitis)<sup>[77-79]</sup>. However, during the following years, laparoscopic pancreatic surgery concentrated on laparoscopic staging of pancreatic cancer and a few reports with small numbers of drainage-procedures in cases of post-pancreatitis pancreatic pseudocysts<sup>[80-87]</sup> were also published. In 2001 the first larger series of 19 patients with laparoscopic pancreatic resection was reported by Patterson *et al.*<sup>[88]</sup>, again raising the question of the usefulness of laparoscopic pancreatic surgery<sup>[89]</sup>. A question which still seems to be current in 2013 as the total number of laparoscopic resections is still quite small<sup>[90-95]</sup>. So by now, there is no evidence for the practicability of laparoscopic pancreatic surgery as good-quality comparative studies are still lacking and thus laparoscopic pancreatic surgery should only be performed within the context of clinical studies.

## LOWER GI TRACT

During the last 25 years colorectal surgery has profited from two relevant innovations: The adoption of the laparoscopic technique which was introduced in the mid 1980s<sup>[2-4]</sup> and the implementation of the concept of fast-track postoperative rehabilitation by Henrik Kehlet in the late 1990s<sup>[96,97]</sup>. Due to the fact that colorectal resections for both benign and malign indications are aside from cholecystectomy the most frequently performed visceral operations, laparoscopic colorectal surgery has been widely accepted in the surgical community and has been investigated in many high-quality studies. Thus today the laparoscopic technique should be preferred in colorectal resections for most indications.

The first laparoscopic colorectal resections were reported in 1991 with various indications<sup>[98-102]</sup>. The surgical community was skeptic and so numerous articles raising questions about the effectiveness and safety of laparoscopic colorectal surgery followed only one year later<sup>[103,104]</sup>. Especially the question of oncological adequateness aroused over the following years<sup>[105,106]</sup>, and it was the group of Steven Wexner of the Cleveland Clinic who claimed patience, since reliable oncological results can only be achieved after five years at the earliest<sup>[107]</sup>. Also, there were the same problems in laparoscopic colorectal surgery for colorectal cancer, similar to those after cholecystectomy for gallbladder carcinomas<sup>[45-47]</sup>, namely surgical site metastasis at the trocar sites<sup>[108-110]</sup>, a topic which is still up to date<sup>[111]</sup>. However, the number



of patients who underwent the laparoscopic surgery rose quickly and in 1995 Ballantyne<sup>[112]</sup> presented a review of 752 patients who had undergone laparoscopic colorectal resections. He came to the conclusion that patients who undergo laparoscopic colorectal resections have fewer complications, less pain and shorter hospital stay-which is all the important advantages of laparoscopic gastrointestinal surgery-compared to open colorectal resections. Interestingly, this was an accepted opinion during the following years, probably due to an appropriation of the results from other laparoscopic fields to colorectal surgery. However, a recent review on the same topic concluded that the impact of the laparoscopic technique on the early postoperative outcome is not as high as expected<sup>[113]</sup> but factors like patient co-morbidities or the severity of a disease play a greater roll. This must be further evaluated as there is still a lack of high-quality studies on this topic<sup>[114]</sup>. In the 2000s, indications for laparoscopic colorectal surgery were further extended and today also include surgery for IBD<sup>[115]</sup> or acute diverticulitis<sup>[116]</sup> with promising results of the postoperative outcome. Therefore today, patients with any benign indication for colorectal surgery should be offered the laparoscopic approach.

But what about the malign indications? There are the same aforementioned problems of oncological adequateness and safety of the laparoscopic technique, compared to the standard open surgical approach which seems to be more relevant than in other organ systems due to the frequency of this type of surgery. It took quite longer than expected by Wexner, until in 2004 the question concerning colon cancer was answered by the Clinical Outcomes of Surgical Therapy Study Group<sup>[117]</sup>. Their multicenter RCT included 872 patients at 48 institutions and randomized them into two groups to either open or laparoscopic resection for colon cancer. They found no difference between both groups regarding the primary endpoint time of tumor recurrence with a median of 4.4 years. The Colon Cancer Laparoscopic or Open Resection (COLOR) Study Group came to the same conclusion<sup>[118]</sup>. They investigated the oncological adequateness of laparoscopic colonic resection for colon cancer in 1076 patients with a median follow-up of 53 mo. Despite a slightly higher 3-year-overall survival in the open surgery group (84.2% *vs* 81.8%) the authors justify the implementation of laparoscopic colonic resection for colon cancer into clinical practice. The third large RCT regarding laparoscopic colorectal resections for colorectal cancer is the United Kingdom MRC CLASICC Trial<sup>[119]</sup>. The researcher investigated 794 patients who were undergoing surgery for colorectal cancer and randomized them to either the laparoscopic group or the open surgical approach group. The overall survival, as well as the disease-free survival showed equivalent numbers in both groups for colonic resections and rectal resections. However, the circumferential resection in rectal cancer did not show equally satisfying results in the laparoscopic group, leaving some concerns regarding the recommendation to perform rectal resections laparoscopically<sup>[120]</sup>.

However, this final issue regarding the oncological equivalency of laparoscopic rectal resections will soon be answered. In 2013, preliminary results (*e.g.*, perioperative data like morbidity or histopathological findings) of the COLOR-II-trial were presented. This multicenter RCT which compares the oncological safety of laparoscopic rectal surgery to open surgery for rectal cancer investigated 1044 patients<sup>[121]</sup>. The authors found no difference regarding oncological radicalness between both groups but found the “typical” laparoscopic advantages in the secondary endpoints such as less blood loss, shorter time until bowel function or shorter hospital stay. Long-term oncological data can be expected at the end of 2013.

So far, by now laparoscopic surgery for colon cancer has been proven to be equivalent to open surgery regarding oncological outcomes with the additional general advantages of laparoscopic surgery and therefore should be offered to the patients. Laparoscopic rectal surgery can be offered by experienced surgeons but always with the awareness that there is still a lack of a final prove that oncological safety is given in this subgroup of patients with colorectal cancer.

## CONCLUSION

In conclusion, laparoscopic gastrointestinal surgery has evolved dramatically over the last three decades and provided an important improvement in the patient-centered care. The perioperative morbidity and mortality could be cut down significantly by reducing the surgical trauma. From the technical point of view, any gastrointestinal resection can be performed laparoscopically today. For the most frequent operations like appendectomy, cholecystectomy, bariatric procedures and colorectal resections it exists high-quality evidence of the benefits or at least evidence of the equivalency of laparoscopy versus open surgical approach. Laparoscopic resection has become the gold standard approach to these procedures no matter if the indication results from a benign or malign disease in the case of colorectal cancer. In the hands of experienced minimally invasive surgeons, those more complex and less frequently performed procedures (esophagectomy, oncological gastrectomy, liver and pancreatic resections) can be carried out safely. However, the question whether there is an equivalent oncological outcome compared to the open approach in these indications still is unanswered by now and have to be proven by future studies.

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