Laparoscopic colectomy: why we do what we do-lessons learned

James Fleshman

Department of Surgery, Baylor University Medical Center, Dallas, Texas, USA

Correspondence to: James Fleshman, MD, FASCRS, FACS. Department of Surgery Baylor University Medical Center, Dallas, Texas, USA. Email: james.Fleshman@BSWHealth.org; james.fleshman@baylorhealth.edu.

Abstract: Many of the methods we use in Laparoscopic colectomy are derived from experience by early adopters and the learning curve experiences. A summary of these pearls is helpful and some information as to why they have been adopted can help trainees and late adopters understand the reason for the techniques. Once a surgeon understands the reason for a technique it should be incorporated in the armamentarium of the surgeon. While this may read like a history article, I believe it can still have the desired effect to strengthen technique for all readers.

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Introduction

In the field of Surgery, paradigm changes occur infrequently and rarely last long before being replaced by another change that amplifies or negates the original change. Laparoscopic techniques have been a paradigm change for colorectal surgery. A minimally invasive approach to a maximal resection of the large intestine defies most logical trains of thought. The size of the target organ, the extent of the area covered by the colon and rectum within the abdominal cavity, the relationship of the colon and rectum to other internal organs, the vascular supply from multiple feeding arteries and draining veins, the variable lymphatic drainage system relating to different areas of the intestinal tract and the multi-quadrant nature of any resection of the colon all defy the logic of a minimally invasive approach to a resection of the colon and rectum. These are the hurdles that have been overcome during the development of minimally invasive approaches to the resection of the colon and rectum. Laparoscopy has been our initial attempt of overcoming these barriers.

The bold step to limit access incision size was slowly accepted across the world. The variety of surgical interventions through a laparoscopic approach expanded after success was achieved in laparoscopic cholecystectomy. The molasses-like pace to expand the approach to other areas of the abdomen (especially the colon and rectum) was frustrating as surgeons had to relearn the techniques for intestinal resection using no hands and discover planes of dissection created by embryologic fusion throughout the abdominal cavity and retro-peritoneum. Rigid remote end-effector laparoscopic tools, which lack haptic feedback and work with reverse angles, as in using a fulcrum, require a learning curve which demands deliberate practice by the surgeon to regain the speed of automaticity that has been part of open operations for all time. Flexibility and wristed action at the effector are still not perfect and only recently became possible with robotic computerized motion. This section will provide a short discussion of the barriers that had to be overcome since 1991, when the first laparoscopic colectomy was successfully performed, and the myriad changes in all aspects of surgery to establish laparoscopy as a viable approach to minimally invasive resection of the colon and rectum.

Instrumentation

The development of colorectal laparoscopic instrumentation was a true partnership between surgeons and industry to create a new set of safe, practical and functional tools to accomplish colorectal resection. The instruments originally developed for cholecystectomy and oophorectomy were unsuitable for the most part for use in colorectal surgery. Groups of surgeons collaborated with industry engineering groups to design and trial the new products and, in a short period of time, produced a usable toolkit. That partnership spirit has rarely occurred to the extent experienced in the early 1990's, as we tried to catch up with the demand for new tools and used new ideas to overcome barriers to minimally invasive approaches for colorectal disease. Industry grants for institutional resources were made available and both academic and community institutions were involved. Training and research units grew up in all areas of the country and addressed issues such as abdominal cavity access, hollow viscus dissection, retraction, tissue capture and protected extraction, vessel ligation and sealing, anastomotic stapling and suturing, pneumoperitoneum pressure activation and maintenance, and patient fixation on the operating table.

The benefits of the reduction in the size of the anterior abdominal wall incision were unknown when it was first suggested that the colon and rectum could be removed with laparoscopic techniques. There was no indication of a maximum tolerated incision length that will result in better recovery by a patient. Early instruments were 10 mm in diameter to provide maximum function at the end effector. Attempts were made at all stages of progress to continually reduce the size of the instruments passing through ports in the abdominal wall. Starting with 1 to 2 cm diameter, the ports and instruments continually decreased in diameter to a lower limit of a 19-gauge needle. Operability was sacrificed at that small size and a compromise was achieved at 3 to 5 mm diameter to allow stiffness of the instrument shaft for mechanical advantage, cable control of the end effector and handle grips that made possible the function of the handles out of the line of site. The effort to reduce the size of trocars and instruments utilized in ablative therapy really doesn't apply to colorectal surgery. A resection is followed by extraction of a large specimen and a re-anastomosis requires access to the abdominal cavity through an incision larger than a trocar in most cases. The weight of the colon full of stool initially was a barrier to the use of more flexible 5 mm instruments but a simple bowel preparation to empty the colon was a practical solution. Duplicating function of open instrumentation at the end of a long shaft with a workable handle was always the goal in the early days of instrument development.

Laparoscopes

The first rigid laparoscopes with a non-enhanced eyepiece provided a prohibitively small view of the cavity beneath the abdominal wall, limited lighting and, essentially, a narrow 2-dimensional view of a large 3-dimensional world. The difficulty of laparoscopic operations and extremely high risk to the patient served to limit the use of the laparoscopy for small areas of resection or repair in a single quadrant of the abdomen. The gynecological conditions of endometriosis, pelvic abscess and ovarian cysts showed us that a laparoscopic approach for these small diagnostic and therapeutic interventions could be performed safely. What was needed was a wider, brighter view and a dome under which to work. The video laparoscope and the Carbon dioxide insufflation were a bold step to push us towards ability to work with full view of the planned resection site. Prism induced angulation of the view of a rigid laparoscope brought flexibility to the use of the technique when a straight view was not helpful. Eventually a flexible tip and a 3-dimensional (3D) view became available which also allowed vision of deep tissues covered or protected by other organs. Before 3D laparoscopes were developed, surgeons compensated by watching the tissue move against the dissecting instrument and relating the size of the tissue to the instrument tip to estimate the distance and relative position.

Gravity as a retractor

There are impediments to successful laparoscopic resection of the colon and rectum which also raise the risk benefit ratio unless they are managed appropriately. Retraction of a hollow viscus with a pinching grasper can result in perforation, either immediate or delayed. The floppy, memoryless nature of the colon and small intestine makes retraction of the viscera difficult and requires the permanent presence of an internal retractor to provide exposure. Eventually, surgeons realized the utility of gravity for moving bowel away from a working interface when the patient was placed in extreme positions. The fixation of the patient to the operating table while in steep airplane right or left and steepest Trendelenburg position is essential to maintain exposure and protect the patient from injury due to sliding or creation of pressure points or nerve stretch. At first, taping and strapping of the legs and chest were used to secure the patient. After discovering the possible complications of this methodology, a deflated bean bag Velcro-fixed to the table and cocooning the patient became an acceptable method. The limitations of the bean bag fixation were nearly the same as the straps, with pressure point and nerve stretch as the major risks, and the limitations of instrument mobility around the patient as the rigid bean bag stopped the instruments from reaching optimal angles in many instances. Fortunately, space technology produced the micro foam mattress for astronaut sleeping stations. The patient on the operating table, lying on the foam pad secured to the usual operating table cushion, sinks into the micro foam which eliminates risk of pressure and stretch during extreme positioning. A single soft strap across the chest prevents shifting of the upper body during tilt.

Medial to lateral approach

Open removal of a portion of the colon usually starts by lateral release of the attachments of the colon to the retroperitoneum and the side wall of the abdomen, followed by ligation of the vessels centrally near the aorta and at the origins of the segmental feeding vessels. Initially, surgeons tried to duplicate the open approach simply using laparoscopic access and instruments. During laparoscopic colectomy, as the standard lateral to medial dissection along the walls of the abdomen progresses to release the colon, the now mobile portion of the bowel eventually becomes an obstruction to visibility. The camera (placed typically at the umbilical port) is covered by the specimen falling medially. For this reason, a medial to lateral approach has more recently been used to lift the colon from the retroperitoneal structures, leaving the bowel attached to, and suspended from, the side wall of the abdomen. The camera view is rarely obstructed by redundant, released tissue since the lateral attachments are in place to the last part of the dissection.

Rules of dissection and exposure

Three-point triangular retraction is facilitated by the medial to lateral approach. This essential method of exposure is necessary to facilitate visualization and create tension on the tissue for incision to be accurate and safe. Points of attachment between colon and walls of the abdominal cavity dictate where the tension and upward or medial traction can be applied to maximize visualization of the planned dissection triangle. Creating progressive triangles of exposure has become the safety standard that prevents mobilization of the retroperitoneal structures by mistake and untoward events such as ureteral injury, vessel damage and laceration of viscus. Surgeons must be disciplined to fully expose as much as possible through each exposure triangle using blunt dissection in the embryologic planes to speed the operation and create enough space to make the next exposure triangle possible.

Another principle of exposure is to use constant adjustment of the exposing instrument in the non-dominant hand to achieve and maintain maximal lift and tension to the tissue being dissected. In fact, a common mistake made by the learning laparoscopic surgeon is to forget the essential contribution of the exposing instrument and focus mostly on the energy source or dissecting instrument in the dominant hand. My favorite warning when a novice laparoscopist is beginning to struggle pertains to "what is the non-dominant hand doing to help the dissection?". More benefit is derived from the exposing instrument than the dissecting instrument.

Working-in-line with the camera is a basic principle and extremely important to help surgeons adjust to 2-dimensional views while working in multiple abdominal quadrants. It is common to see residents and fellows looking at a video monitor in a direction away from the working site within the abdomen and struggling to move the instrument into the working area. The principle of lining up the instrument insertion site, camera insertion site, working area in the abdomen and a video monitor will limit confusion at the start of the learning curve. Working opposite camera or out of line is a complex skill that can be developed but should not be the preferred method of working. This principle requires multiple monitors to be available for colorectal cases and a team of operating room staff that understands this principle.

The best way to teach laparoscopic colorectal surgery has not been developed. The method that has helped the most to this point has been through simulation of a particular resection in a fresh frozen (non-fixed) cadaver model. The original training paradigm was to use live mid-sized animals to teach the basics of vessel control and dissection techniques with different energy sources. However, this was so far from reality that there was no transfer of technique to the patient. After trials of using inanimate models failed, a test of dissections in alcohol fixed cadaveric models struck a chord with the majority of us who were teaching courses in laparoscopic colectomy. The benefits of seeing human intra-abdominal anatomy from a laparoscopic view and learning how to reach planes safely for the resection in each section of the intestine are realized only in a human cadaveric model. It is now incorporated in the simulation training for general surgery and colorectal residents to pave the way to learning in the operating room. We are thankful to individuals who have donated their bodies to this effort. Efforts are underway to develop a virtual system that mimics the cadaver model as artificial intelligence grows in sophistication and reality.

Laparoscopic technique and colorectal cancer: research

In the early days of laparoscopic treatment of colon cancer, delayed trocar and extraction site wound implants of cancer were reported. Was this a warning signal of inadequate surgical technique or an inherent problem of the laparoscopic method? Subsequent animal experiments and clinical data have clearly shown that violation of even early stage cancer within the abdominal cavity during laparoscopic dissection is responsible for the implants or carcinomatosis. Tumor extraction through a small abdominal wall incision with a wound protector can prevent implants of tumor in these wounds. High flow air leaks around a trocar can result in tumor implants in the abdominal wall if there are aerosolized cells from the surface of the tumor as a result of aggressive tumor handling. Even with good technique and careful tumor handling the act of sharply cutting across a vessel (lymphatic or vein) containing tumor due to vascular invasion may result in aerosolization of tumor and subsequent abdominal wall implants or carcinomatosis. Sealing all of the vessels in the area of the tumor and maintenance of the integrity of the embryological mesenteric envelope isolates the tumor cells in the resected specimen and accomplishes a surgical complete resection.

The controversy around the appropriateness of laparoscopic resection of colorectal cancer stimulated an entire generation of Colon and Rectal Surgeons to become involved in research to answer a number of relevant questions regarding the cancer treatment outcomes delivered by laparoscopic techniques. The energy that arose from that debate was felt internationally. Simultaneous efforts were initiated on multiple continents to use randomized controlled trials to answer the question of whether minimally invasive operative techniques, and which ones, could provide the best outcomes for patients with colon cancer and more recently rectal cancer. The bottom line was, within limits of course, yes. The unanticipated benefit of this surge in research and data collection and development of informal research consortia within our colorectal society were ongoing projects looking at surgical techniques in general, evaluation of new technology, standardization of training methods and simulation to expand adoption of surgical technique, credentialing of surgeons to participate in research based on review of videos of their technique, comparison of short term outcomes and long term outcomes separately, proctoring of surgeons for privileging in advanced laparoscopic techniques at the hospital level and a focus on evaluating operative competency for colorectal surgery.

Laparoscopic energy sources

As laparoscopy evolved and greater demands for more advanced abdominal operations grew, new energy sources for dissection and management of vessels followed. The standard radiofrequency electrical energy sources for tissue dissection were found to be inadequate for vascular control until they were modified with pressure-based sealing and tissue impedance feedback. Ultrasound was converted to an energy source for tissue dissection and vessel sealing with limits. The first vessel control systems relied on pre-tied trocar friendly suture loops, staples of smaller height in modified delivery endoscopic staplers or modified automatic clip appliers. Each of these carried risks and limits. In the process of learning how to get high frequency alternating current energy from the hand grip of 35 cm long instruments to the functioning tip of a curved scissors or a hook cautery we discovered the impact of capacitance coupling, stray current through insulation defects on the metal shaft of the instruments, indirect spread of current by unintentional direct coupling, variable depths of heat and current spread by sealing bipolar instruments, microwave transmission of heat to long instruments serving as antennae and tolerance limits of vessel size for sealing with bipolar electrocautery. The complications associated with all of these resulted in delayed problems: fistulas, vascular hemorrhage, and intra-abdominal abscesses. Awareness fortunately brought prevention and the frequency of these problems has returned to a rare occurrence.

Hand assisted laparoscopy

Long straight instruments with single dimensional straight-ahead function at the effector frustrated all laparoscopic surgeons. The limited haptic feedback of straight laparoscopy and the need to place more trocars to give a different angle of access for instruments to impact the organ of focus eventually led to the addition of hand-assisted approaches to difficult laparoscopic cases and as an adjunct to training paradigms for beginners. The initial hand-assisted efforts were cumbersome and maintenance of a pneumoperitoneum was difficult. After the introduction of a gel disc and an elastic iris as an abdominal wall port through which to place the hand, this technique facilitated the learning curve for many new laparoscopists and accelerated the ability to perform complex cases and shortened the excessive times for early laparoscopic cases.

Laparoscopic anatomic considerations

Developing skill in the in the use of laparoscopy for colectomy is based upon the ability to recognize anatomic landmarks from a video perspective in close proximity to the tissue and from a position parallel to the retroperitoneal surface rather than an above-looking-down point of view typical of an open operation. The identification of embryologic fusion planes between the intra-abdominal organ and the muscles of the abdominal wall allows one to enter a dissection zone without large blood vessels. Areolar tissue, looking like “cotton candy”, occupies this plane and melts in response to electrical injury and pulls apart with minimal mechanical force. Until laparoscopy came to be a frequently used modality most surgeons were unaware of these very consistent planes. The blunt entry into mesenteric fat, not the embryologic plane, resulted in bleeding, vascular and visceral injury, inadequate resection of colon for cancer and diverticulitis, and collateral damage to hidden adjacent critical structures. Until atlases of laparoscopic colon surgery were available (1-6), the only mechanism for passing along this information was essentially by word of mouth via video presentation at societal meetings and shared videos by visiting professors at laparoscopic training seminars. Eventually, institutional video collections, video publication in peer reviewed journals and social media have made access to video anatomy readily available and the best source for successful preparation for a laparoscopic case.

Certain spatial relationships within the abdomen have been shown to greatly impact the safe dissection of the large intestine in multiple quadrants of the abdomen. The Lesser Omental Sac behind the stomach and greater omentum, anterior to the body and tail of the pancreas, cephalad to the transverse colon mesentery is a clear area that landmarks the path of dissection to safely release the splenic flexure of the colon from a posterior approach. The inferior mesenteric vein (IMV) as it enters the undersurface of the pancreas to join the portal vein points the way to the space. Dividing the IMV between the pancreas edge and the first venous branch to the mesentery of the left colon exposes the mesentery of the transverse colon fused to the anterior surface of the pancreas and becomes a window to the Lesser Sac. We can safely incise this window and extend the incision out to the tip of the pancreas and over the anterior surface of the left kidney and eventually release the colon safely from the attachment to the splenic pedicle from a posterior approach.

The anterior surface of the Duodenum on the right side of the midline at the base of the Transverse Mesocolon is a safe plane that guides the posterior dissection around the hepatic flexure of the colon. Creating separation of the colonic mesentery from the surface of the duodenum protects the superior mesenteric artery from injury, exposes the origin of the ileocolic vascular pedicle and lifts the hepatic flexure of the colon from the anterior surface of the duodenum and right kidney. Final incision of the posterior suspensory ligaments of the hepatic flexure at the undersurface of the liver edge opens the embryologic plane behind the right colon. A medial to lateral dissection of the right colon depends on the knowledge of these anatomic relationships.

Another areolar tissue plane anterior to the sacral promontory can be entered at the right side of the pelvic brim by incising the peritoneum under tension to expose a potential space filled with “cottony” tissue that can be pushed posteriorly to expose the left Iliac Artery and protect the left ureter traversing the iliac artery. The undersurface of the arch of the inferior mesenteric artery (IMA)/superior hemorrhoidal artery is encased in the peritoneal mesorectal envelope. Following this plane to the origin of the IMA at the aorta and down into the posterior pelvis is key to a complete total mesorectal excision for rectal cancer.

Procedural steps

Most procedures can be broken down into 4 or 5 general reproducible steps. Several authorities have documented these steps in national publications and textbooks and there is general agreement on most of the basics. These steps guide the placement of trocars and patient positioning, flow of the dissection and vascular isolation and ligation, complete organ isolation and anatomic dissection before resection, extraction and re-anastomosis. Consideration of the potential issues with the anastomosis must be dealt with before the anastomosis is performed in a laparoscopic case because the majority of the developing of a tension free, well vascularized anastomosis occurs during the portion of the case under pneumoperitoneum. The mobilization of the splenic or hepatic flexures during a resection of the left and right colon, respectively, is key to this aspect of the preemptive management or prevention of complications. Hand-assisted laparoscopic resection plays a large role in reducing the stress of this part of the operation.

A look to the future

As surgery moves through the next iterations of a minimally invasive approach the lessons learned from the laparoscopic era must inform the development, evaluation and quality assurance process for the next generation. We have stood on the shoulders of the open surgeons as we developed confidence in our laparoscopic capabilities. Choosing the appropriate outcomes that signify success in disease treatment and patient quality of life should be set prior to the initiation of new technology. Our greatest hurdle in medicine as a whole is affordability of high-quality care. It is incumbent on us to develop value-based approaches to the diseases we treat and to avoid the use of new technology as simply a marketing tool to look for volume in the practice. Where a less expensive but less glitzy approach might provide the same treatment and patient quality outcome, we should not hesitate to rely on the more fundamental value focused approach. That is another way to say that laparoscopic approaches still have a role in today's treatment of colorectal disease.

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Footnote

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