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Laparoscopic oncologic proctosigmoidectomy with low colorectal anastomosis in a cadaver model

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Abstract. The purpose of this study was to demonstrate that a standardized approach to laparoscopic proctosigmoidectomy in a cadaver model with (1) initial proximal ligation of the inferior mesenteric (IM) vascular pedicle, (2) complete mobilization of the splenic flexure, and (3) intraperitoneal stapled colorectal anastomosis can be accomplished in complete accordance with oncologic surgical principles. Using nine cadavers in the fresh state, six abdominal wall cannulas were placed so as to allow good access to the left colon and rectum. After identifying the left ureter and gonadal vessel, the IM pedicle was divided close to the aorta and the left mesocolon was separated from the retroperitoneal structures. The sigmoid colon was transected at the proximal resection line with an endoscopic stapler; then the splenic flexure and descending colon were completely mobilized. The rectum was freed circumferentially, dissected first posteriorly, laterally, and anteriorly, and then transected in its middle portion with an endoscopic stapler. The specimen was removed through a widened left-lower-quadrant trocar incision and the anvil of a circular endoscopic stapler was placed into the proximal colon extraperitoneally. An intraperitoneal laparoscopic colorectal anastomosis was performed using a double-stapled technique. The median length of specimen was 53 cm (range 45–80 cm) and the median number of removed lymph nodes was 15 (range 11–20). A careful abdominal autopsy was carried out in all cadavers. Length of remaining inferior mesenteric artery was smaller than 1.5 cm in all cases and only one remaining lymph node (3 mm in diameter) was found adjacent to the IMA in one subject. No damage to either ureter occurred. All colorectal anastomoses were patent without signs of air leakage or defects on air insufflation and gross inspection. Using this standardized laparoscopic technique, it is possible to perform a proctosigmoidectomy with stapled intraperitoneal anastomosis according to oncologic surgical principles.

Key words: Laparoscopy — Proctosigmoidectomy — Colorectal cancer — Oncologic resection

Colorectal cancer is the leading indication for large bowel resection in the United States. As interest in performing laparoscopic colorectal procedures increases, [1, 6, 8, 14, 15, 17–23, 28] so too does the necessity of evaluating the intraoperative efficacy and feasibility of laparoscopic techniques applied to colorectal cancer surgery.

Within the last several years, various articles have reported the use of laparoscopic techniques in the surgical management of colorectal malignancies [14, 19, 21]. None of these reports, however, has convincingly demonstrated that use of laparoscopic techniques can accomplish a resection according to accepted surgical oncologic principles.

So that we might verify whether laparoscopic bowel resection may be achieved according to oncologic principles [7, 11, 25–27], we designed a standardized method for the performance of oncologic proctosigmoidectomy with colorectal anastomosis in a cadaver model followed by a complete abdominal autopsy to reveal the extent of surgery in an irrefutable manner.

Thus, the purpose of this study was to demonstrate in a fresh human cadaver model that a standardized laparoscopic technique of oncologic proctosigmoidectomy with intraperitoneal colorectal anastomosis is feasible.

Methods

The hypothesis of our study is that a laparoscopic proctosigmoidectomy can be performed according to oncologic surgical principles.

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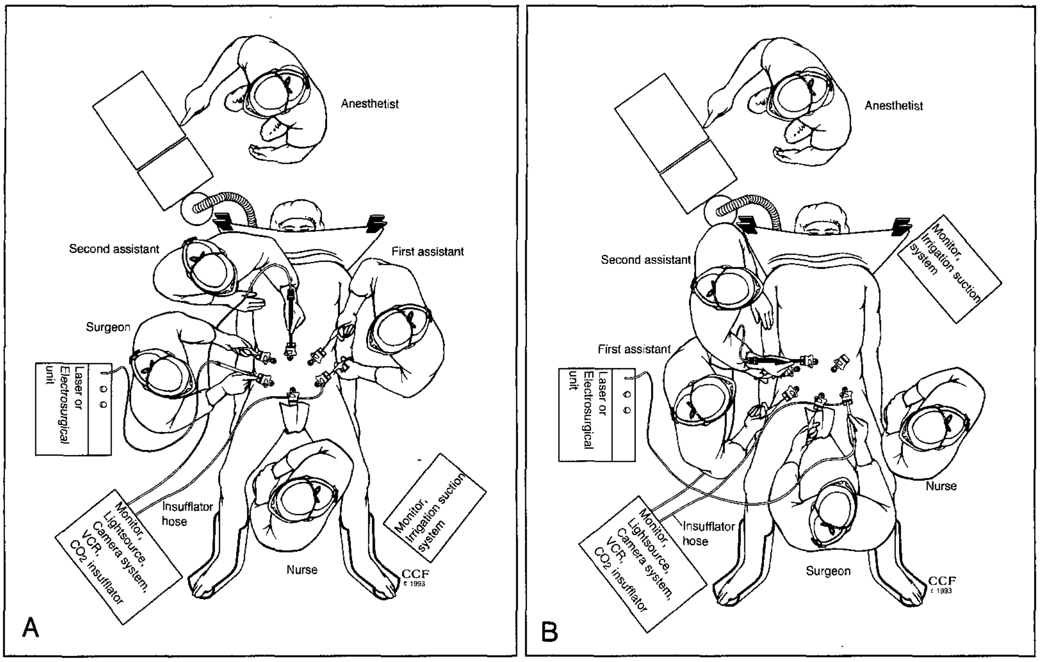


Fig. 1. A Location of surgeon, first assistant, second assistant (cameraman), nurse, and equipment for laparoscopic proctosigmoidectomy at the first and third part of the operation. **B** Location of surgeon, first assistant, second assistant (cameraman), nurse, and equipment for laparoscopic proctosigmoidectomy at the second part of the operation.

The endpoints of the study are intraoperative complications (injuries to major blood vessels, ureter, intestine, or anastomotic problems), initial vascular ligation of inferior mesenteric artery (IMA) within 1.5 cm of its origin before mobilizing the colon, complete removal of mesocolon and mesorectum including all lymph nodes adjacent to the named intestinal visceral arteries, and safe laparoscopic formation of a colorectal anastomosis.

Cadavers

In order to test our hypothesis, *9 cadavers (8 males and 1 female) obtained in a fresh state (expired between 72 and 88 h before surgery)* received injection of an ethanol and glycerin solution via the femoral artery to reduce rigor mortis. Vigorous preoperative massage of the abdominal wall muscles was also performed to soften them. The colon was prepared with cleansing tap water enemas.

After laparoscopic resection, a thorough abdominal autopsy inspecting all surgical sites was accomplished in all cadavers.

This study was reviewed and approved by the Institutional Review Board of The Cleveland Clinic Foundation, Cleveland, Ohio (Research Programs Committee #4023) and the Ethics Committee of the Central Military Hospital, Federal District, Mexico. Cadavers were procured through the Forensic Medical Service of Mexico City after being unclaimed for 72 h after death. Mexican legal codes permit medical research on cadavers if unclaimed after 72 h.

Oncologic resection

A suitable oncologic resection of colorectal carcinoma could be defined as follows [7, 11, 25–27]: (1) resection of all known extent of cancer in the bowel wall and adjacent soft tissue; (2) resection of a suitable margin of bowel wall above and below the cancer; and (3) excision of draining regional lymph nodes accompanying the major vascular pedicles to the involved bowel (mesocolon/rectum).

According to these principles, oncologic proctosigmoidectomy was defined in this study as an en bloc resection of the rectosigmoid with its mesentery, a proximal ligation of IMA with remaining vessel length less than 15 mm, and removal of all lymph nodes belonging to the sigmoid mesocolon or mesorectum. Although the named vessels can theoretically be ligated immediately at their origin, we adopted a technique of leaving a slightly longer vessel stump so that in case of bleeding (in the living human) an additional ligation or clip could be applied.

After laparoscopic oncologic proctosigmoidectomy, the excised specimen was examined by an experienced pathologist. The length of the removed intestine and number of excised lymph nodes were documented.

An autopsy was carried out in all cadavers and the number of remaining lymph nodes at the origin of IMA was recorded. The length of the remaining IMA was measured in millimeters.

Technique of laparoscopic oncologic proctosigmoidectomy

Cadavers were placed in a modified lithotomy position with legs abducted 45–60° in the Trendelenburg position (15–20° head down). The shoulders, chest, and legs were securely strapped to the table. *Pneumoperitoneum up to 30 mmHg* was established with a Surgineedle (United States Surgical Corporation, Norwalk, CT) and the first trocar was inserted through an infraumbilical skin incision. Initially, the surgeon and cameraman stood on the right side of the subject and the assistant on the left side (Fig. 1a). The nurse with the instrument table was positioned between the legs. Two monitors were located at the right and left foot of the subject to allow access to the perineum.

Different locations of trocars (Surgiport Trocars, US Surgical) were tested and the following sites (Fig. 2) appeared to give optimum approach to the pelvis, sigmoid colon, splenic flexure, and IMA. The first tro-

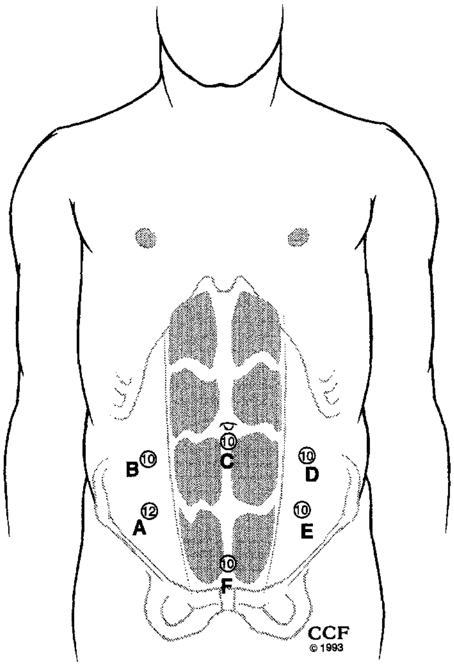


Fig. 2. Location and size of trocars for laparoscopic proctosigmoidectomy. Rectus muscle with epigastric vessels.

car was inserted just below the umbilicus. Two trocars were inserted in both the right and left lower quadrants. They were arranged in an open half-circle to the pelvis. The distance between the trocars was not less than 8 cm to prevent "scissoring" and obstruction of movement between instruments. In general, placement of the trocars depended on the configuration of the abdomen.

After placement of the first trocar, a high-resolution laparoscopic telescope/camera was inserted and all additional trocars were placed under visual control. The cadaver was tilted with the right side down so that the small intestine fell into the right upper quadrant. The peritoneum to the right of the IMA was incised to the origin of the IMA at the abdominal aorta (Fig. 3). The IMA was elevated and the dissection continued posteriorly and to the left of the IMA until the ureter and gonadal vessel were identified and swept posteriorly away from the sigmoid mesentery. The IMA was ligated above its left colic branch using an endoscopic stapler (Multifire EndoGIA 30–2.5 (V) Stapler, US Surgical) (Fig. 4). Although the IMA was dissected to its origin, we preferred to leave the vessel 1–1.5 cm long so that if any bleeding occurred in an actual human situation an additional ligation could be applied. Next, the mesocolon was dissected to the left until the inferior mesenteric vein (IMV) was identified and clipped with endoscopic clips (Large Endoclip Applier, US Surgical) or transected with an endoscopic stapler.

The sigmoid mesocolon was mobilized posteriorly in a medial to lateral fashion. The left ureter, gonadal vessel, and Gerota's fascia were identified and further swept away from the mesentery. The lateral attachments were dissected and the sigmoid colon completely mobilized (Fig. 5). The proximal resection line was specified and the mesosigmoid transected at this juncture using an Nd:YAG Contact Laser (Surgical Laser Technologies Inc., Oaks, PA) or scissors with monopolar electrosurgery. All mesenteric/marginal vessels were clipped and the colon was transected with an endoscopic stapler (Multifire EndoGIA 30, US Surgical) (Fig. 6).

At this point, the surgical team repositioned itself (Fig. 1b) and the cadaver was placed in reverse Trendelenburg (15–20° head up) with the assistant applying medial retraction to the descending colon endoscopic graspers (EndoGrasp, US Surgical) so that the lateral and dorsal attachments of the descending colon and splenic flexure could be divided. If the splenic flexure proved difficult to dissect, the dissection was continued from the distal transverse colon. The greater omentum was detached and the splenic flexure was completely mobilized.

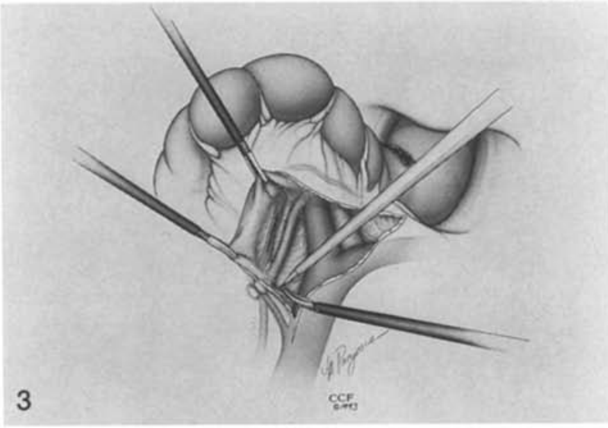
The surgical team rearranged itself once again (Fig. 1a). The rectum was completely mobilized to the pelvic floor using standard "open technique" principles starting with posterior mobilization (Fig. 7), then dissecting posterolaterally on the right and left site. Large vessels of the lateral ligaments were clipped and soft tissue was cut flush with the pelvic sidewalls. Finally, anterior dissection to a level below the seminal vesicles was carried out. The assistant maintained traction on the rectum using a grasping instrument on the rectum and a second instrument to apply tension to the perirectal soft tissue.

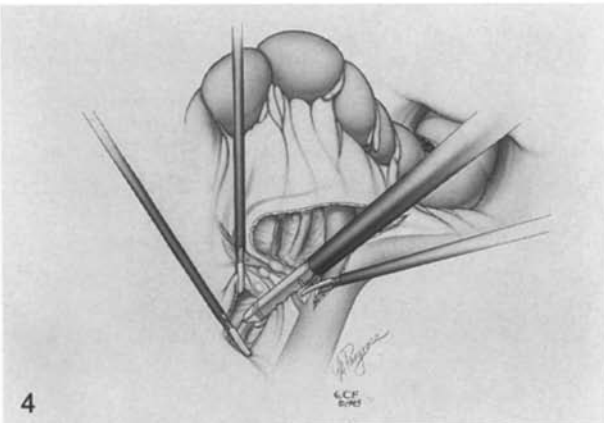
The distal mesorectum was divided sharply starting on the right side at the proposed level of transection, clipping any large inferior rectal branches. The hoop retractor modified from a laparoscopic bag to catch a gallbladder specimen (EndoCatch, US Surgical) was placed below the tumor and the bowel lumen was occluded.

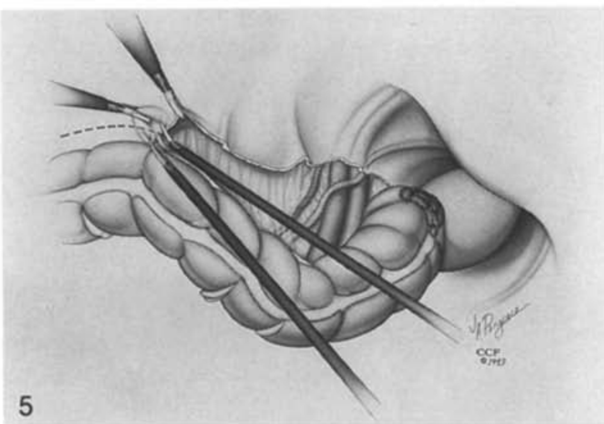
In patients, a rectal washout with a cytotoxic solution would be performed at this point. A 15-mm cannula then replaced the right-lower-quadrant 10-mm cannula. A 60-mm endoscopic stapler (Multifire EndoGIA 60—3.5-mm staplers, US Surgical) was used through this site to transect the rectum below the hoop retractor (Fig. 8). Through the left lower quadrant (LLQ) cannula an endoscopic Babcock (EndoBabcock Instrument, US Surgical) was used to grasp the specimen, and through the left upper quadrant (LUQ) cannula the proximal bowel was grasped. The LLQ cannula was removed and the opening was enlarged transversely in a muscle-splitting fashion to 4–5 cm, the specimen was delivered, and the proximal colon was exteriorized with the previously placed LUQ grasper.

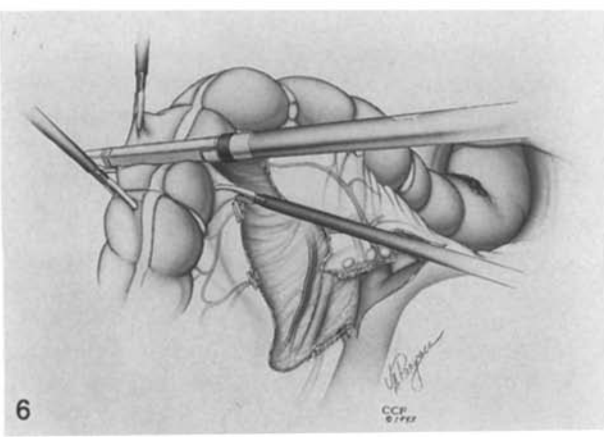
A purse-string (0 polypropylene) suture was placed around the cut edge of the proximal colon after excising the endoscopically placed staplers. The anvil of a 28- or 31-mm circular stapler (Premium CEEA Stapler, US Surgical) was then placed into the bowel lumen, and the purse-string was tied in the usual fashion. The colon was returned to the abdominal wall, which thereafter was closed with size 0 polyglycolic acid sutures through the fascia.

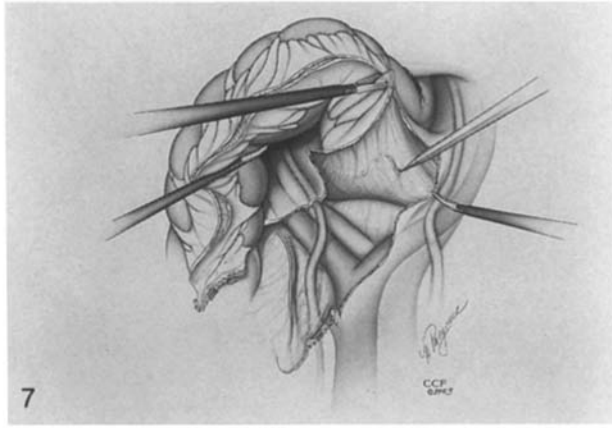
Pneumoperitoneum was reestablished, and the cir-











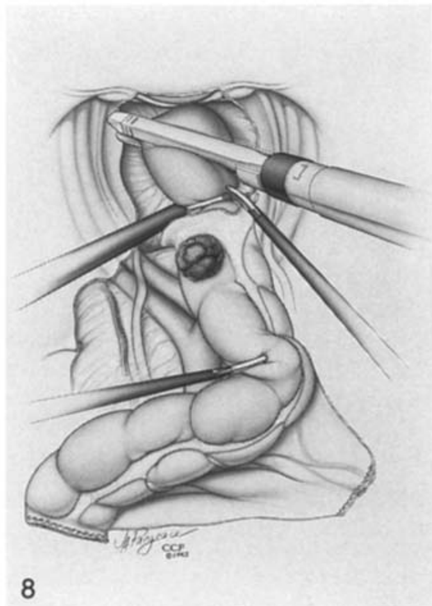


Fig. 3. The dissection commences with an incision in the retroperitoneum to the right of the inferior mesenteric artery.

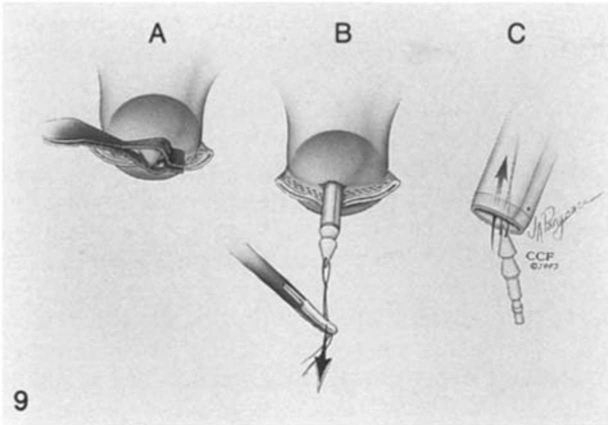
Fig. 4. Endoscopic linear stapler ligating and dividing the inferior mesenteric artery close to its origin. Ureter and gonadal vessel have been swept clear from the vessels. The inferior mesenteric vein may be ligated simultaneously.

Fig. 5. Dissection of the lateral attachments of the left colon.

Fig. 6. Transection of mesosigmoid using clips and of sigmoid colon using endoscopic stapler is carried out.

Fig. 7. Mobilization of rectum posteriorly.

Fig. 8. The rectum is transected distal to the loop retractor using a 60-mm linear endoscopic stapler.



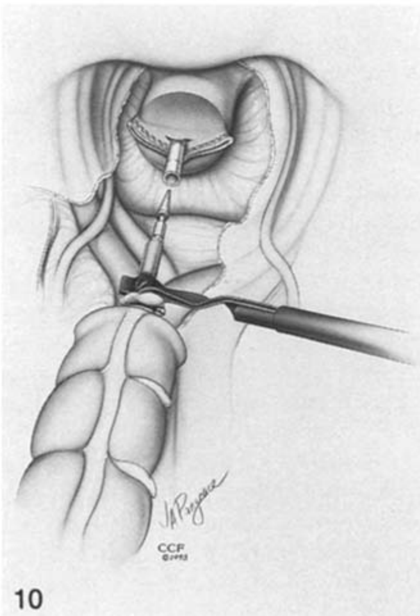


Fig. 9. A Plastic spike of circular stapler is starting to push through rectum, aided by countertraction using an endoscopic Babcock clamp. **B** Spike is pushed through the rectum close to the staple line. **C** Spike is removed through a trocar by pulling on the attached thread.

Fig. 10. The colorectal anastomosis is effected using a roticulating Endobabcock instrument to maneuver the centerrod into the centerpost of the transanally placed Premium CEAA instrument.

cular stapler was passed transanally with a modified detachable plastic trocar placed into the head of the instrument. The instrument was fully inserted into the rectum, the spike was passed through the rectal wall adjacent to the staple line, and an attached thread was used to dislodge the trocar and remove it from the peritoneal cavity (Fig. 9).

A standard double-stapling technique was used to form the colorectal anastomosis, grasping the groove in the center rod with a right-lower-quadrant (RLQ) endoscopic Babcock instrument (EndoBabcock, US Surgical) and locking it into the circular stapler. Excellent visualization of the anastomosis prior to firing the stapler was possible (Fig. 10).

Air insufflation of the rectum using a proctoscope was performed after filling the pelvis with saline solution to test the anastomosis for leaks.

Results

Laparoscopic proctosigmoidectomy with colorectal anastomosis was performed in nine fresh male cadavers with a median age of 32 years (range 25–49). The median operative time was 150 min (range 130–240) and decreased with surgical experience during the study. The median length of specimen was 53 cm (range 45–80 cm) and the median number of removed lymph nodes was 15 (range 11–20).

A long midline incision was made in each case to perform a thorough autopsy. The median length of remaining IMA was 5 mm (range 1–15). In one case, a remaining lymph node was found (3 mm in diameter) at the origin of the IMA. The left gonadal vessel was injured in one case in the first procedure. No damage to either ureter occurred. All colorectal anastomoses were patent without signs of air leakage.

Discussion

It is now feasible to resect and anastomose all parts of the large intestine without a conventional incision using laparoscopic surgical techniques [1, 6, 8, 14, 15, 17–23, 28]. However, the possible benefits of "laparoscopic colorectal surgery" (such as decreased pain, smaller incision, and earlier recovery of postoperative ileus) pale in significance when compared with the assurance that adequate oncologic resection has been performed.

In three recent articles reporting laparoscopic colorectal operations, the most common indication for surgery was adenocarcinoma [14, 19, 21]. No description of the extent of resection nor location of mesenteric vascular ligation was given by Phillips et al. [21], who reported 24 colectomies for colorectal cancer. They referred to an average of 14 lymph nodes per specimen removed, but these data have no correlation with an adequate cancer operation. From a surgical oncologic perspective, it is not acceptable to argue that "the extent of lymph node dissection is dependent on the skill of the operator and his or her determination to widely resect the mesentery" (p. 706) [21]. In another series reporting 11 colectomies for colorectal cancer, Jacobs et al. [14] did not describe their technique or location of ligation of the main mesenteric vessels either. Six of their cancer resections were performed with a curative intent in which "an attempt was made to remove as much of the primary lymph node-bearing tissues as possible" (p. 149) [14]. These articles have not demonstrated that adequate cancer surgery was performed. They have only vaguely stated that they intended to accomplish a curative resection for colorectal cancer.

Although the length of the removed specimens and the number of removed lymph nodes following laparoscopic curative colectomies for colorectal cancer were reported by Monson et al., neither did they describe precisely how they have accomplished an oncologic resection [19].

A large number of excised mesenteric lymph nodes is not proof that an oncologic resection was performed. Since there is a broad range in the number of resected lymph nodes after all reported resections for colorectal cancer [2, 10, 12, 13, 24], Scott and Grace [24] have reported that in order to accurately stage 90% of colorectal cancers, a retrieval of at least 13 lymph nodes from the specimen is necessary. This does not mean that a special number of excised lymph nodes guarantees that an oncologic resection was performed, only that identifying a specific number of lymph nodes allows the pathologist to stage a high percentage of tumors accurately. The only number of lymph nodes which would prove that oncologic resection has been accomplished is the number of remaining lymph nodes.

In our study, we defined adequate cancer surgery according to principles found in authoritative works in colorectal cancer surgery [7, 11, 25–27]: (1) resection of all known extent of cancer in the bowel wall and adjacent soft tissue, (2) resection of suitable margin of bowel wall above and below the cancer, and (3) excision of draining regional lymph nodes accompanying the major vascular pedicles to the involved bowel (mesocolon/rectum).

There has not yet been a published report demonstrating whether a laparoscopic oncologic resection of colorectal cancer can be performed according to these surgical standards. We felt that prior to attempting these laparoscopic techniques in patients, it was essential to prove that an adequate laparoscopic cancer operation is feasible.

Laparoscopic surgery in a human cadaver model was an excellent opportunity to prove our hypothesis since an autopsy was used to verify and document adequate anatomical resection of the rectosigmoid, adjacent mesentery, and soft tissue.

This study allowed us not only to show that a laparoscopic oncologic proctosigmoidectomy is feasible but also to design a standardized technique (described above) which may permit an adequate oncologic resection. A radical laparoscopic oncologic proctosigmoidectomy with intraperitoneal colorectal anastomosis will undoubtedly be accomplished more safely and effectively in patients when performed with such a systematic approach.

We carried out very proximal ligation of the IMA (range 1–15 mm) in all cases to prove the feasibility of radical removal of the rectosigmoid lymphatic drainage. In actual practice, such extreme proximal ligation may not be optimal due to risks of bleeding. The described procedure contradicts MacFadyen et al. [16], who stated, "laparoscopically . . . major blood vessels are not easily identified until the colon has been removed."

There was one cadaver with a single remaining lymph node at the origin of the IMA. This node was 3 mm in diameter and was not, in our opinion, indicative of an inadequate cancer operation.

One criticism of this study is that the abdominal wall was not quarantined from the resected bowel segment upon removal. In patients with colorectal malignancies, the intestine must be placed into a sealed "bowel bag" prior to removal through an abdominal incision to prevent any possibility of tumor implantation in the abdominal wall. This apparatus was not available at the time of the study, but must be used in curative laparoscopic bowel surgery.

Since laparoscopic intestinal surgery is in its infancy, and no long-term data are available regarding results in oncologic colorectal surgery, we feel this study answers several critical questions. Using the anatomical and surgical criteria we have outlined here, we have shown that, laparoscopically, the IMA can be divided and ligated close to the aorta, the splenic flexure can be freed from its attachments, and a radical resection of the rectal and sigmoid mesentery can be performed with a colorectal anastomosis in the pelvis using laparoscopic techniques.

Although this study cannot address physiological questions such as bleeding and anastomotic leakage in laparoscopic intestinal surgery (which we have evaluated in animal models) [3–5], only a study such as this, using human cadavers in a fresh state with postoperative autopsy, can verify that an adequate primary colorectal cancer operation can be performed using laparoscopic techniques.

Since reliable results of a prospective randomized study comparing recurrences and long-term survival between "open" and laparoscopic surgery will not be available for the next 5 to 10 years, the question as to whether a curative proctosigmoidectomy for colorectal cancer be accomplished laparoscopically with the same outcome as in "open" surgery cannot be answered yet. In the meantime, we believe the laparoscopic surgeon should follow a standardized approach to proctosigmoidectomy for cancer which has been proven anatomically to result in a comparable resection according to accepted oncologic principles. Furthermore, the laparoscopic surgeon must in each procedure prove that an oncologic curative resection has been performed using the video documentation available at surgery or convert to a standard "open" procedure using a traditional abdominal incision.

Conclusion

This study illustrates a step-by-step approach for the performance of an oncologic proctosigmoidectomy with intraperitoneal colorectal anastomosis using laparoscopic techniques.

It proves that a proximal ligation of the IMA with wide clearance of the lymphatic drainage of the rectosigmoid, takedown of the splenic flexure, and colorectal anastomosis can be accomplished laparoscopically.

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