ANNALS OF SURGERY
Vol. 221, No. 1, 29-42

Peritonectomy Procedures

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Objective
New surgical procedures designed to assist in the treatment of peritoneal surface malignancy were sought.

Background
Decisions regarding the treatment of cancer depend on the anatomic location of the malignancy and the biologic aggressiveness of the disease. Some patients may have isolated intra-abdominal seeding of malignancy of limited extent or of low biologic grade. In the past, these clinical situations have been regarded as lethal.

Methods
The cytoreductive approach may require six peritonectomy procedures to resect or strip cancer from all intra-abdominal surfaces.

Results
These are greater omentectomy-splenectomy; left upper quadrant peritonectomy; right upper quadrant peritonectomy; lesser omentectomy-cholecystectomy with stripping of the omental bursa; pelvic peritonectomy with sleeve resection of the sigmoid colon; and antrectomy.

Conclusions
Peritonectomy procedures and preparation of the abdomen for early postoperative intraperitoneal chemotherapy were described. The author has used the cytoreductive approach to achieve long-term, disease-free survival in selected patients with peritoneal carcinomatosis, peritoneal sarcomatosis or mesothelioma.

Peritoneal carcinomatosis from colorectal malignancy always has been regarded as a lethal clinical condition. Recently, a new strategy for treatment of established colorectal tumor implants within the abdominal cavity has been reported. A rationale for these treatments, based on the natural history of large bowel cancer, has been presented.[1-12] An interpretation of the pathobiology that regulates the distribution of cancer deposits within the abdominal cavity has been proposed.[13] A pharmacologic basis for intraperitoneal chemotherapy administration as adjuvant therapy in the early postoperative period has been established.[14-16] The prognostic features that would allow proper patient selection has been recorded. These studies show that the lesser the extent of peritoneal carcinomatosis and the lower its invasive and metastatic potential, the better the results of cytoreductive treatment. The cytoreductive approach, combining surgery and intraperitoneal chemotherapy as a single event, has been described.[7,16-18] To optimize this treatment strategy, one attempts to achieve maximal cytoreductive effects of sur-

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Accepted for publication July 8, 1993.

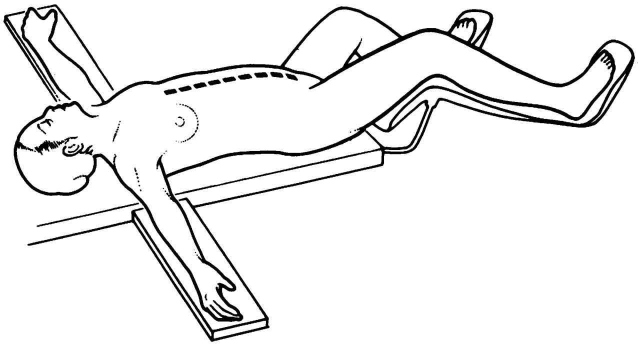

Figure 1. Position and incision.

gery and combine these with the maximal cytoreductive effects of intraperitoneal chemotherapy used in the early postoperative period. The morbidity (37%) and mortality (2%) has been described, and the problems encountered with fistula formation have been analyzed.[19] A critique of a new approach to adjuvant intraperitoneal chemotherapy has been presented.[20,21]

This article presents the techniques required to complete six different peritonectomy procedures that are used to resect cancer on visceral intra-abdominal surfaces or to strip cancer from parietal peritoneal surfaces. One or all six of these procedures may be required, depending on the distribution and volume of peritoneal carcinomatosis. This approach has been used in colorectal, appendiceal, ovarian, and small bowel adenocarcinoma. These procedures also may be considered for patients with mesothelioma and peritoneal sarcomatosis.

METHODS

Position and Incision (Fig. 1)

The patient is in a supine position with the gluteal folds advanced to the break in the operating table to allow full access to the perineum during the surgical procedure. This modified lithotomy position is achieved with the legs extended in St. Mark's leg holders (AMSCO, Erie, PA). Proper positioning is essential to avoid intraoperative skin or muscle necrosis. Extra padding is placed beneath the sacrum. The weight of the legs must be directed to the bottom of the feet by positioning the footrests so that minimal weight is borne by the calf muscle. Myonecrosis within the posterior compartment of the leg may occur unless the legs are protected properly. All surfaces of the St. Mark's stirrups are protected by egg crate foam padding. The thigh and legs are surrounded by alternating pressure devices (SCB Compression Boots, Kendall Co., Boston, MA). These should be operative before the induction of anesthesia for maximal protection against venothrombosis. A hyperthermia blanket is placed over the chest, arms, and head of the patient (Bair Hugger Upper Body Cover, Augustine

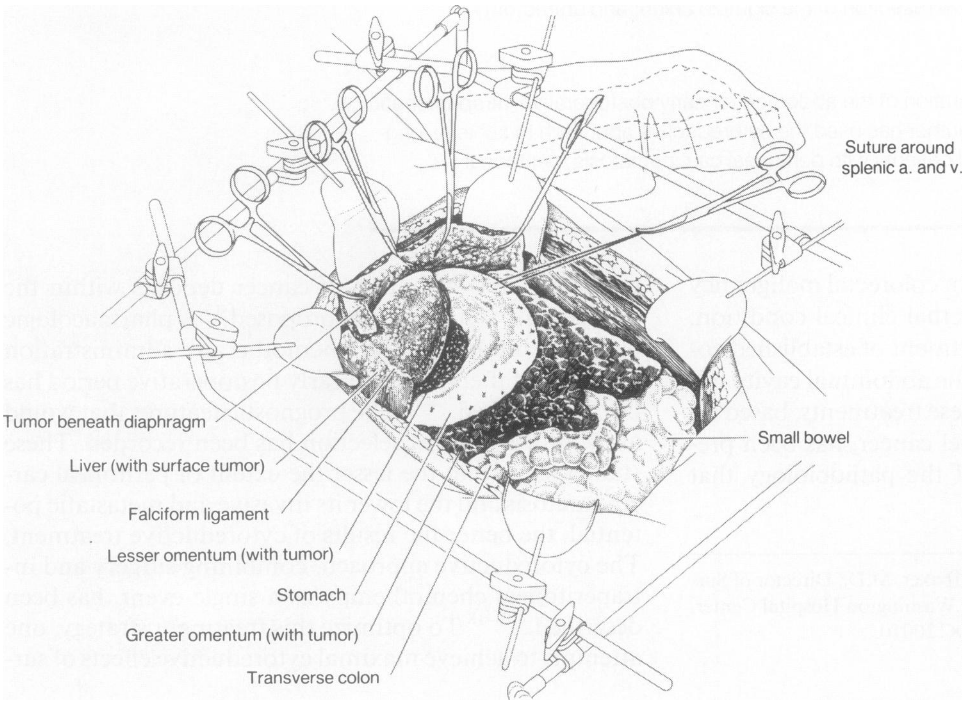

Figure 2. Abdominal exposure, greater omentectomy, and splenectomy.

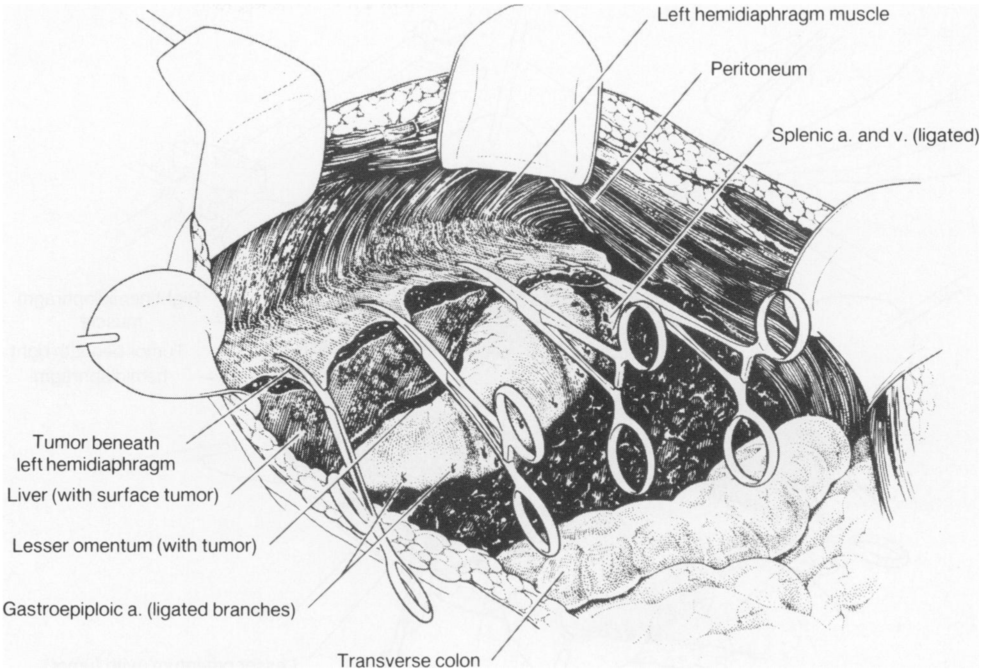

Figure 3. Peritoneal stripping from beneath left hemidiaphragm.

Medical, Eden Prarie, MN) and also beneath the torso (Cincinnati Sub-Zero, Cincinnati, OH).

Abdominal skin preparation is from mid chest to mid thigh. The external genitalia are prepared in the men and a vaginal preparation is used in women. The Foley catheter is placed in position after the surgical preparation

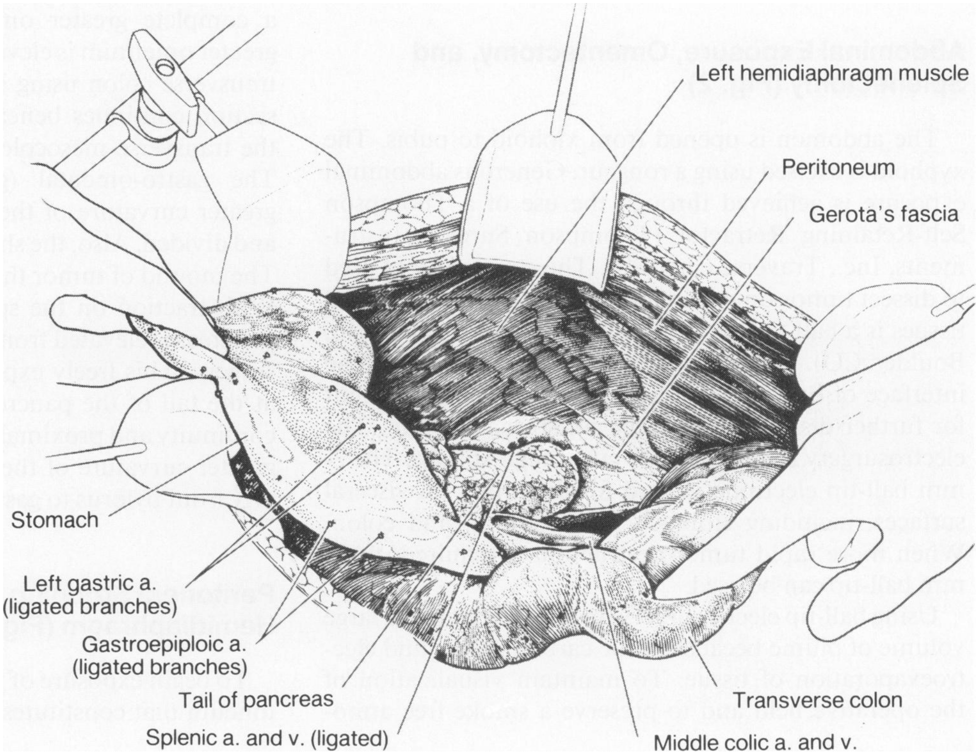

Figure 4. Left upper quadrant peritonectomy, completed dissection.

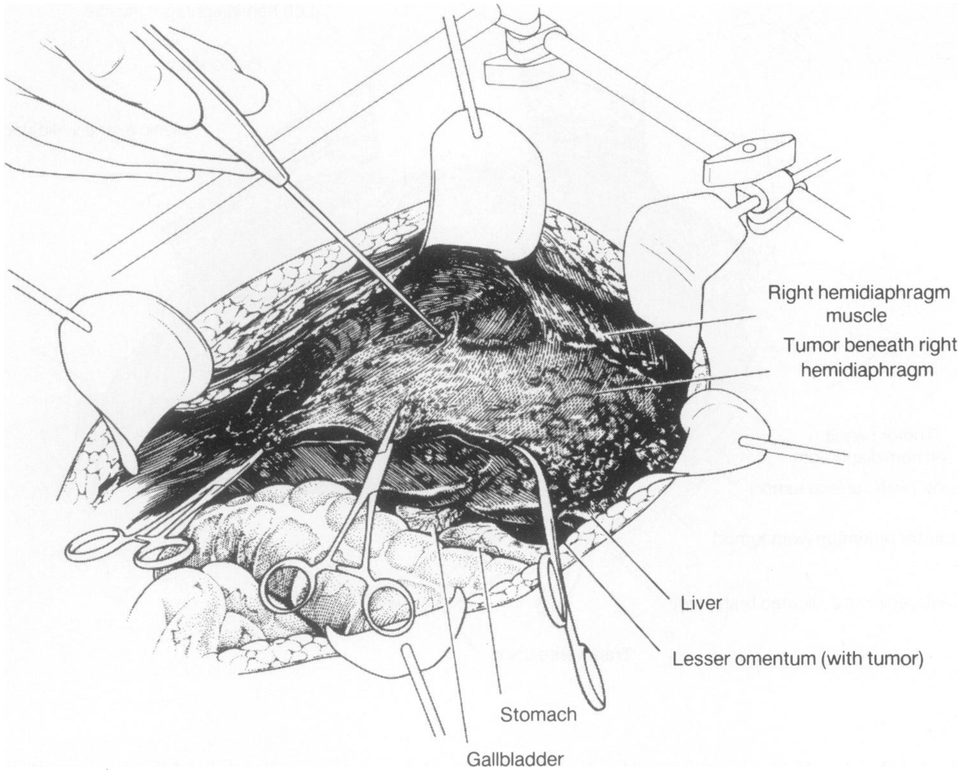

Figure 5. Peritoneal stripping from beneath right hemidiaphragm.

so that this catheter can be accessed during the surgical procedure. A large bore silastic nasogastric tube is placed within the stomach (Argyle Salem Sump Tube, Sherwood Medical, St. Louis, MO).

Abdominal Exposure, Omentectomy, and Splenectomy (Fig. 2)

The abdomen is opened from xiphoid to pubis. The xyphoid is excised using a rongeur. Generous abdominal exposure is achieved through the use of a Thompson Self-Retaining Retractor (Thompson Surgical Instruments, Inc., Traverse City, MI). The standard tool used to dissect tumor on peritoneal surfaces from the normal tissues is a ball-tip electrosurgical handpiece (Valleylab, Boulder, CO). The ball-tipped instrument is placed at the interface of tumor and normal tissues. The focal point for further dissection is placed on strong traction. The electrosurgery is used on pure cut at high voltage. The 2-mm ball-tip electrode is used for dissecting on visceral surfaces, including stomach, small bowel, and colon. When more rapid tumor destruction is required, the 5 mm ball-tip can be used.

Using ball-tip electrosurgery on pure cut creates a large volume of plume because of the carbonization and electroevaporation of tissue. To maintain visualization of the operative field and to preserve a smoke-free atmosphere in the operating theater, a smoke filtration unit is used (Stackhouse Inc., El Segunda, CA). The vacuum tip is maintained 2 to 3 inches from the field of dissection whenever electrosurgery is used.

To free the mid abdomen of a large volume of tumor, a complete greater omentectomy is performed. The greater omentum is elevated and then separated from the transverse colon using ball-tip electrosurgery. This dissection continues beneath the peritoneum that covers the transverse mesocolon so as to expose the pancreas. The gastro-omental (gastroepiploic) vessels on the greater curvature of the stomach are clamped, ligated, and divided. Also, the short gastric vessels are transected. The mound of tumor that covers the spleen is identified. With traction on the spleen, the anterior fascia of the pancreas is elevated from the gland using ball-tip electrosurgery. This freely exposes the splenic artery and vein at the tail of the pancreas. These vessels are ligated in continuity and proximally suture-ligated. This allows the greater curvature of the stomach to be reflected anteriorly from pylorus to gastroesophageal junction.

Peritoneal Stripping from Beneath the Left Hemidiaphragm (Fig. 3)

To begin exposure of the left upper quadrant, the peritoneum that constitutes the edge of the abdominal inci-

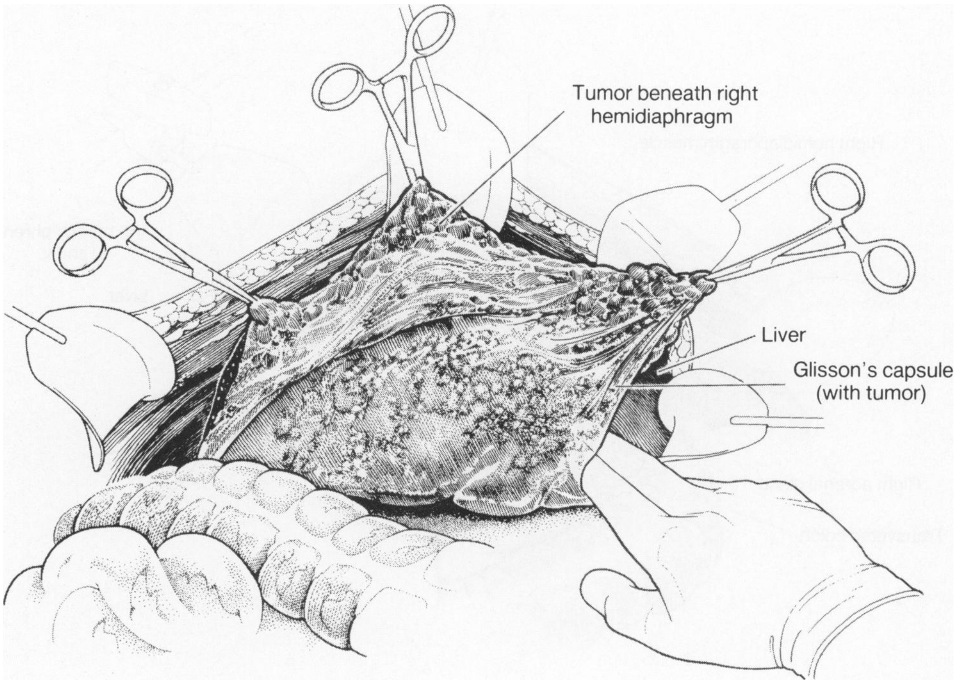

Figure 6. Dissection beneath tumor through Glisson's capsule.

sion is stripped off the posterior rectus sheath. To secure this peritoneal layer, Kelly clamps are positioned approximately every 10 cm. This allows traction to be achieved on the tumor specimen throughout the left upper quadrant.

The left upper quadrant peritonectomy involves a stripping of all tissue from beneath the left hemidiaphragm to expose diaphragmatic muscle, left adrenal gland, superior aspect of pancreas, and the cephalad half of Gerotta's fascia. To achieve a full exposure of the left

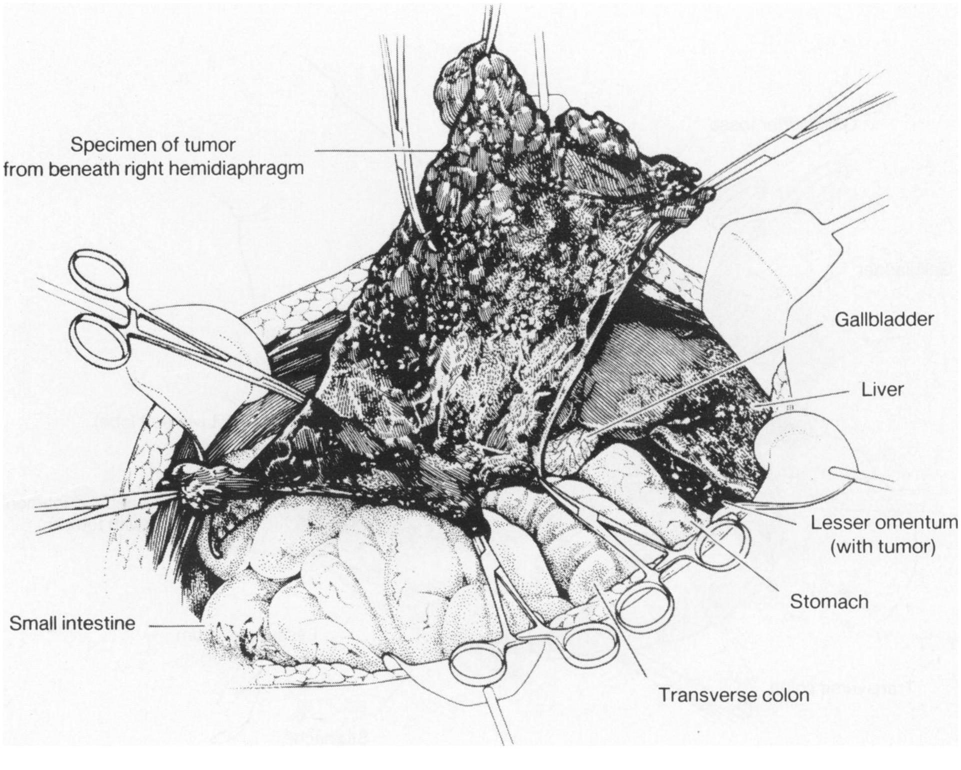

Figure 7. Removal of tumor from beneath the right hemidiaphragm, from right subhepatic space, and from the surface of liver.

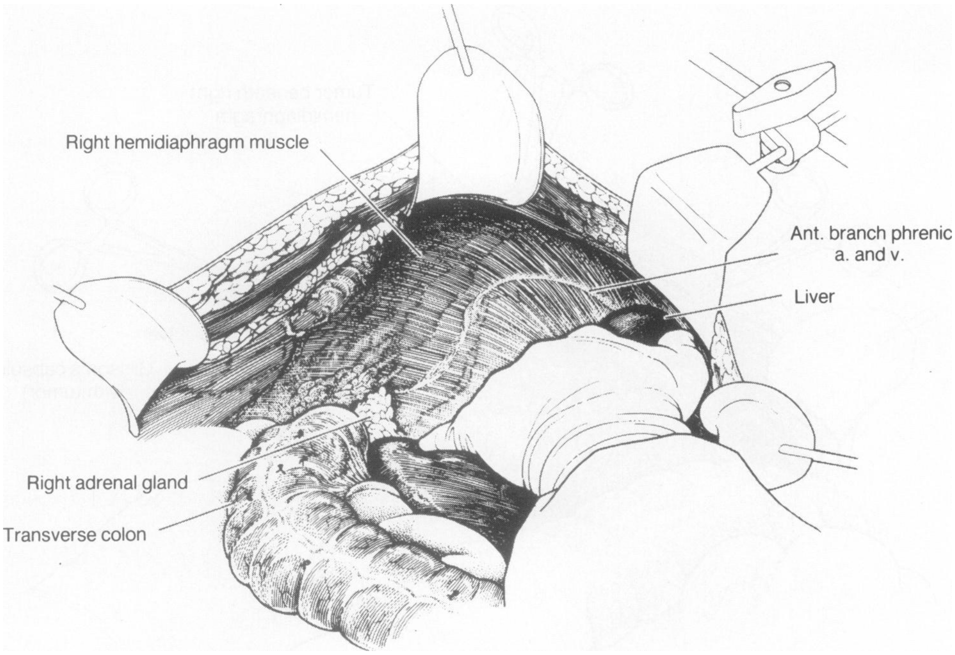

Figure 8. Completed right upper quadrant peritonectomy including stripping of the right subhepatic space.

upper quadrant, the splenic flexure is released from the left abdominal gutter and moved medially by dividing tissue along Toldt's line. The dissection beneath the left hemidiaphragm is performed with ball-tip electrosurgery and not by blunt dissection. Numerous blood vessels between diaphragm muscle and its peritoneal surface must be electrocoagulated before their transection or unnecessary bleeding will occur. Generally, tissue is transected

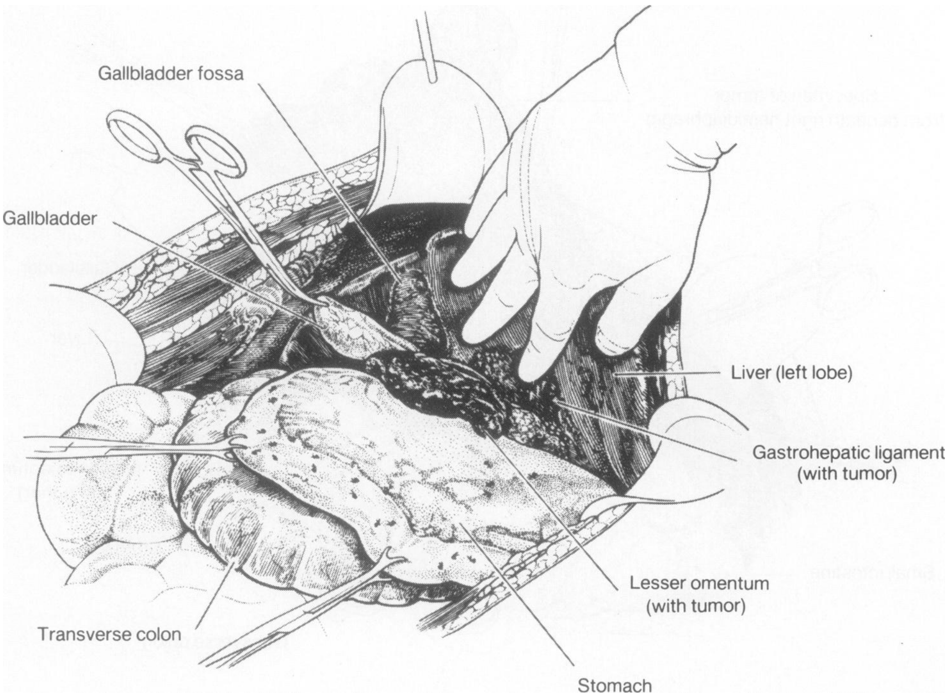

Figure 9. Lesser omentectomy and cholecystectomy.

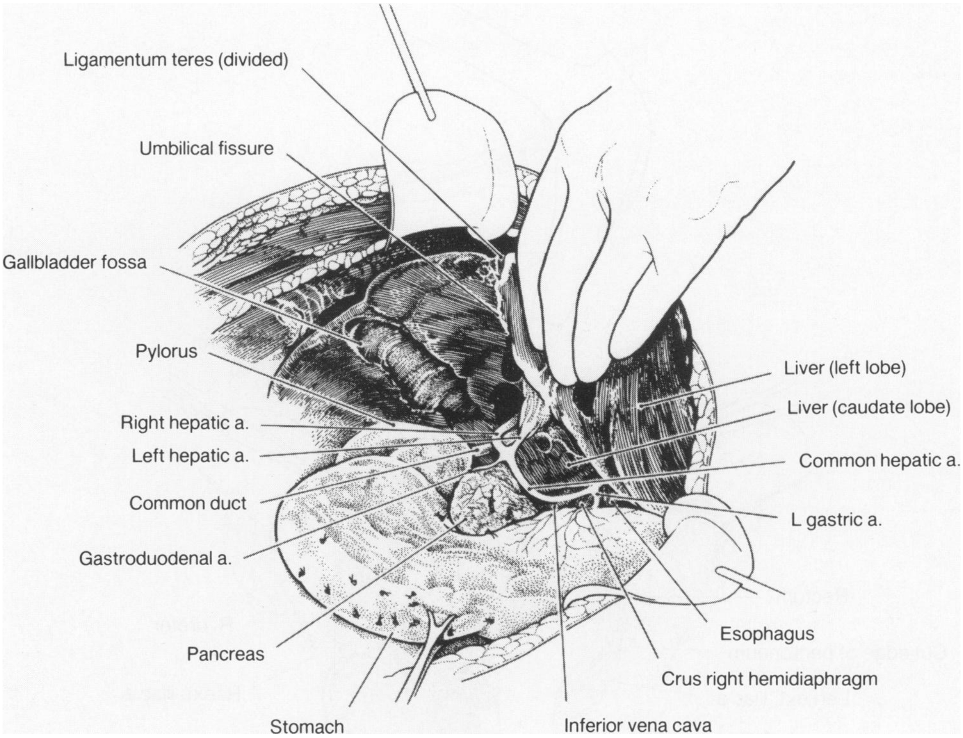

Figure 10. Stripping of the omental bur

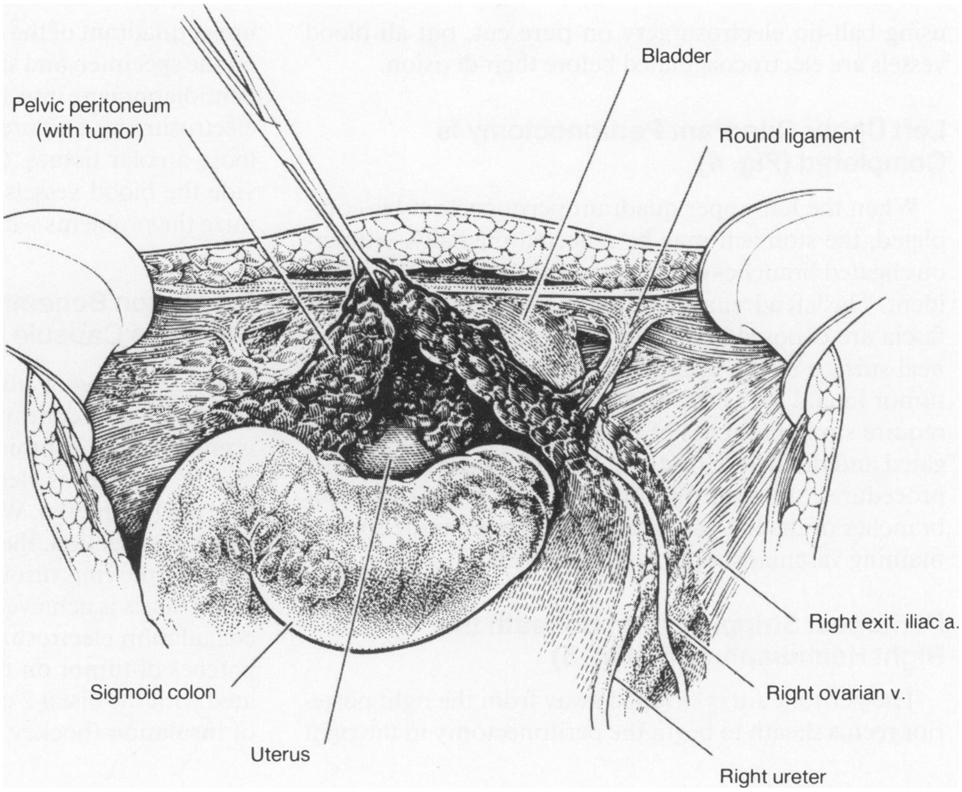

Figure 11. Pelvic peritonectomy.

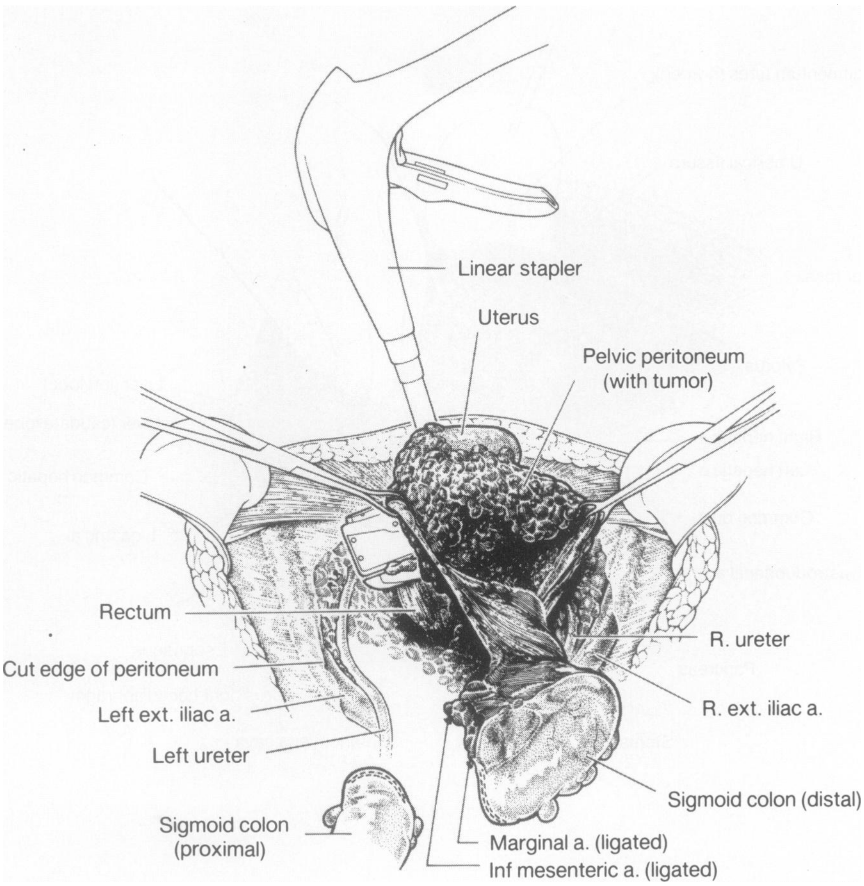

Figure 12. Resection of rectosigmoid colon beneath peritoneal reflection.

using ball-tip electrosurgery on pure cut, but all blood vessels are electrocoagulated before their division.

Left Upper Quadrant Peritonectomy Is Completed (Fig. 4)

When the left upper quadrant peritonectomy is completed, the stomach may be reflected medially. Numerous ligated branches of the gastroepiploic arteries are evident. The left adrenal gland, pancreas, and left Gerotta's fascia are exposed completely, as is the anterior peritoneal surface of the transverse mesocolon. Occasionally, tumor in and along the cephalad border of the pancreas require small branches of the left gastric artery to be ligated and divided. However, with all the peritonectomy procedures, the surgeon must carefully avoid the major branches of the left gastric artery to preserve the sole remaining vascular supply to the stomach.

Peritoneal Stripping from Beneath the Right Hemidiaphragm (Fig. 5)

The peritoneum is stripped away from the right posterior rectus sheath to begin the peritonectomy in the right upper quadrant of the abdomen. Kelly clamps are placed on the specimen and strong traction is used to elevate the hemidiaphragm into the operative field. Again, ball-tip electrosurgery on pure cut is used to dissect through the loose areolar tissues. Coagulation current is used to divide the blood vessels as they are encountered to minimize the problems with postoperative hemorrhage.

Dissection Beneath Tumor Through Glisson's Capsule (Fig. 6)

The stripping of tumor from the muscular surface of the diaphragm continues until the bare area of the liver is encountered. At this point, tumor on the anterior surface of the liver is electroevaporated until the liver surface is encountered. With both blunt and ball-tip electrosurgical dissection, the tumor is lifted off the dome of the liver by moving through or beneath Glisson's capsule. Hemostasis is achieved as the dissection proceeds, using coagulation electrosurgery on the liver surface. Isolated patches of tumor on the liver surface are electroevaporated with the distal 2 cm of the ball-tip bent and stripped of insulation (hockey stick configuration). Ball-tip elec-

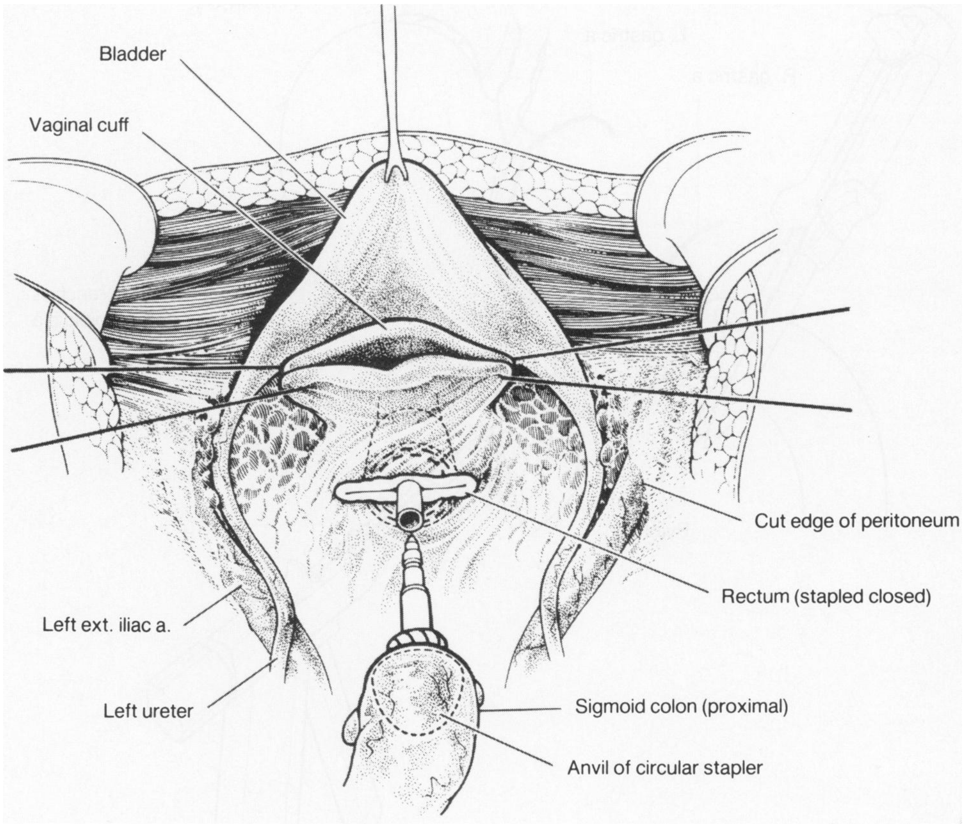

Figure 13. Vaginal closure and colorectal anastomosis.

trosurgery also is used to extirpate tumor from in and around the falciform ligament, round ligament, and umbilical fissure of the liver.

Removal of Tumor from Beneath the Right Hemidiaphragm, from the Right Subhepatic Space, and from the Surface of the Liver (Fig. 7)

Tumor from beneath the right hemidiaphragm, from the right subhepatic space, and from the surface of the liver forms an envelope as it is removed en bloc. The dissection is simplified greatly if the tumor specimen can be maintained intact. The dissection continues laterally on the right to encounter Gerotta's fascia covering the right kidney. Also, the right adrenal gland is visualized as the tumor is stripped from Morrison's pouch (right subhepatic space). Care is taken not to traumatize the vena cava or to disrupt caudate lobe veins that pass between the vena cava and segment 1 of the liver.

Completed Right Upper Quadrant Peritonectomy, Including Stripping of the Right Subhepatic Space (Fig. 8)

With strong traction on the right costal margin and medial displacement of the right liver, one can visualize the completed right upper quadrant peritonectomy. The anterior branch of the phrenic artery and vein are seen and have been preserved. The right hepatic vein and the vena cava below have been exposed. The right adrenal gland and Gerotta's fascia covering the right kidney constitute the base of the dissection.

Frequently, tumor will be densely adherent to the tendinous mid portion of the left or right hemidiaphragm. If this occurs, the fibrous tissue infiltrated by tumor must be resected. This usually requires an elliptical excision of a portion of the hemidiaphragm on either the right or the left. The defect in the diaphragm is closed with interrupted sutures and rarely causes respiratory problems postoperatively.

Lesser Omentectomy and Cholecystectomy (Fig. 9)

The gallbladder is removed in a routine fashion from its fundus toward the cystic artery and cystic duct. These structures are ligated and divided. The plate of tissue that covers the structures that constitute the porta hepatis usually is infiltrated heavily by tumor. Using strong traction, the cancerous tissue that covers the structures is stripped from the base of the gallbladder bed toward the duode-

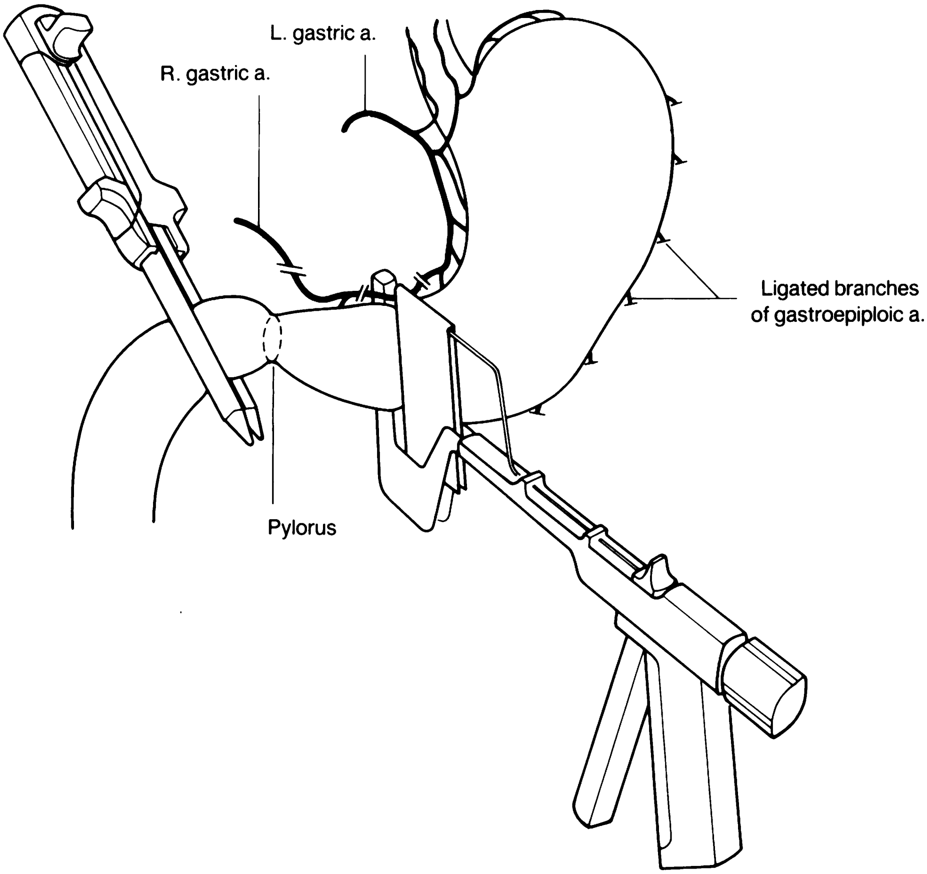

Figure 14. Antrectomy.

num. In this dissection, ball-tip electrosurgery may be excessively traumatic. The delicate structures of the porta hepatis are dissected free of tumor by the spreading action of a clamp. Blade electrosurgery on coagulation current is used to divide tissues above the clamp. To continue resection of the lesser omentum, one proceeds along the gastrohepatic fissure that divides liver segments 2, 3, and 4 from segment 1. One goes back to ball-tip electrosurgery for this maneuver and for electroevaporation of tumor from the anterior surface of the left caudate process. Great care is taken not to traumatize the caudate process for this can result in excessive and needless blood loss. The segmental blood supply to the caudate lobe is located on the anterior surface of this segment of the liver, and hemorrhage may occur with only superficial trauma. Also one must be aware that the left hepatic artery may arise from the left gastric artery and cross to the hepatogastric fissure. If this occurs, one dissects with a spreading clamp along this vessel to isolate it from the surrounding tumor and localize the left gastric artery.

Stripping of the Omental Bursa (Fig. 10)

As one clears the left part of the caudate liver segment of tumor, the vena cava is visualized directly beneath. To begin to strip, the omental bursa strong traction is maintained on the tumor and ball-tip electrosurgery is used to divide the loose fibrous tissue above the vena cava. The crus of the right hemidiaphragm is skeletonized. The common hepatic artery and the left gastric artery are skeletonized and avoided. A spreading clamp with blade electrosurgery is used to visually identify the cephalad and caudad branching of the left gastric artery and the coronary vein. Dissection of lesser omental fat using pressure between the thumb and index finger will help identify these two major branches of the left gastric artery. They are preserved to ensure adequate blood supply to the stomach. At least two major branches of the left gastric artery are required to provide blood supply to the stomach.

The surgeon dissects in a clockwise direction along the lesser curvature of the stomach. Care is taken to preserve as much omental fat as possible. Only tumor tissue is removed. The multiple branches of the vagus nerve to the antrum of the stomach are divided. Finally, dissection using a spreading clamp around celiac lymph nodes allows the specimen to be released.

A pyloroplasty or gastrojejunostomy must be performed to allow the stomach to empty. In the absence

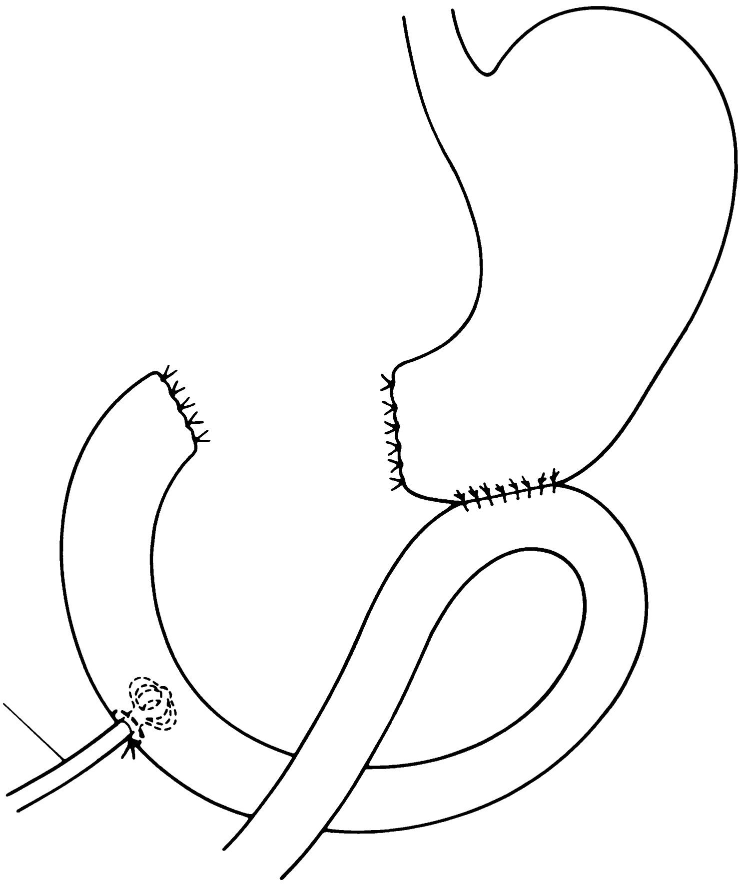

Figure 15. Gastric reconstruction.

of a gastric drainage procedure, gastric stasis will occur because of the vagotomy.

Pelvic Peritonectomy (Fig. 11)

To initiate the pelvic peritonectomy, the peritoneum is stripped from the posterior surface of the lower abdominal incision, exposing the rectus muscle. The muscular surface of the bladder is seen as ball-tip electrosurgery strips tumor-bearing peritoneum and preperitoneal fat from this structure. The urachus must be divided and often is the leading point for this dissection. Round ligaments are divided as they enter the internal inguinal ring on both the right and left in the female patient.

The peritoneal incision around the pelvis is completed by dividing peritoneum along the pelvic brim. Right and left ureter are identified and preserved. In women, the right and left ovarian vein are ligated and divided. A linear stapler is used to divide the sigmoid colon in its mid portion. The vascular supply of the distal portion of bowel is traced back to its origin on the aorta. The inferior mesenteric artery is ligated and divided. This allows one to pack all of the viscera, including the proximal sigmoid colon in the upper abdomen.

Resection of Rectosigmoid Colon Beneath Peritoneal Reflection (Fig. 12)

Ball-tip electrosurgery is used to dissect beneath the mesorectum. One works in a centripetal fashion to free the entire pelvis. An extraperitoneal suture ligation of the uterine arteries occurs just above the ureter and close to the base of the bladder. In women, the bladder is moved gently off the cervix, and the vagina is entered. The vaginal cuff anterior and posterior to the cervix is divided using the ball-tip electrosurgery, and the perirectal fat inferior to the posterior vaginal wall is encountered. Ball-tip electrosurgery is used to divide the perirectal fat beneath the peritoneal reflection. This ensures that all tumor that occupies the cul-de-sac is removed intact with the specimen. The mid portion of the rectal musculature is skeletonized using ball-tip electrosurgery. A roticulator stapler (Autosuture, Norwalk, CT) is used to staple the rectal stump closed.

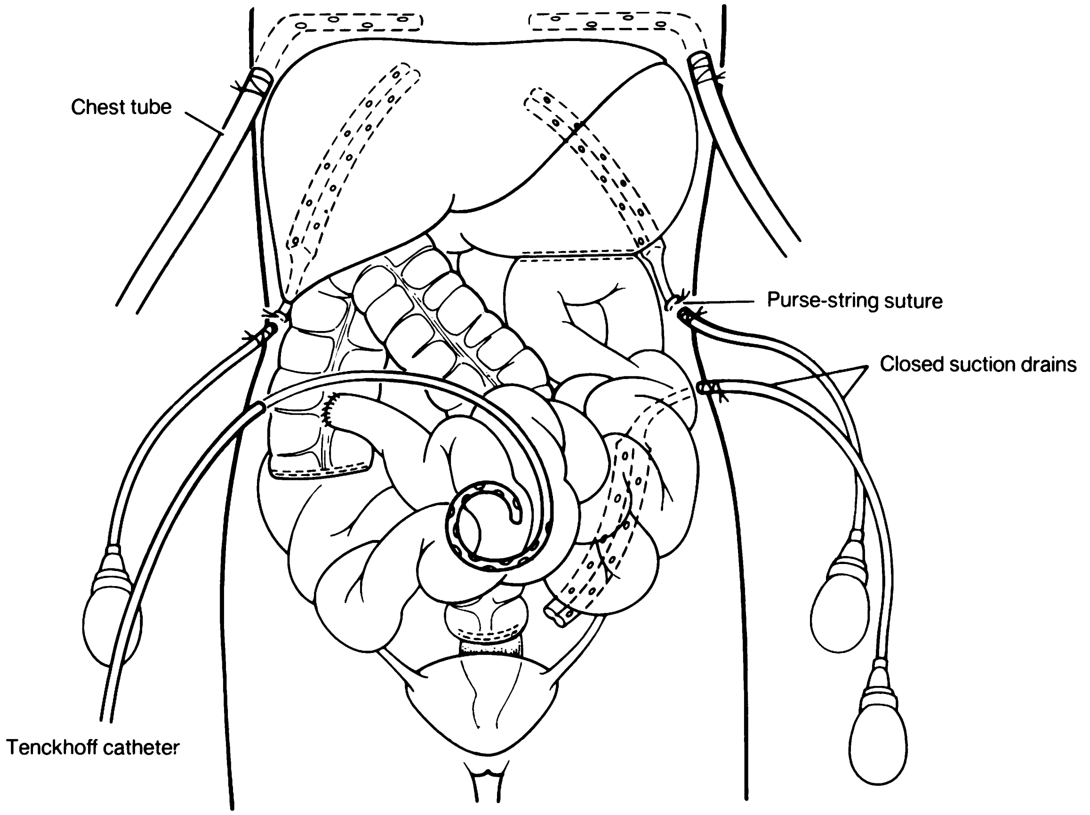

Figure 16. Tubes and drains required for early postoperative intraperitoneal chemotherapy.

Vaginal Closure and Colorectal Anastomosis (Fig. 13)

Interrupted re-absorbable sutures are used to close the vaginal cuff. A circular stapling device is passed into the rectum, and the trochar is used to penetrate the staple line. A monofilament suture placed in a purse-string fashion is used to secure the staple anvil in the proximal sigmoid colon. The body of the circular stapler and anvil are mated, and the stapler is fired to complete the low colorectal anastomosis (Intraluminal Stapler 33, Ethicon, Sommerville, NJ).

An absolute requirement of a complication-free low colorectal anastomosis is an absence of tension on the suture line. Adequate mobilization of the entire left colon is needed. Several steps are required to accomplish this. The inferior mesenteric artery is ligated on the aorta, and its individual branches (superior hemorrhoidal, sigmoid, and left colic) ligated as they arise from this vascular trunk. This allows for great stretching of the left colic mesentery. The inferior mesenteric vein is divided as it courses around behind the duodenum. The mesentery of the transverse colon and splenic flexure are elevated completely from Gerota's fascia. Taking care to avoid the left ureter, the left colon mesentery is divided from all of its retroperitoneal attachments. These maneuvers will allow the junction of sigmoid and descending colon to reach to the low rectal or anus for a tension-free anastomosis.

To ensure a safe colorectal anastomosis, the proximal and distal tissue rings are examined for their completeness. Air is insufflated into the rectum with a water-filled pelvis to check for an air-tight anastomosis. A hand is passed beneath the sigmoid colon to make sure that there is no tension on the stapled anastomosis. A rectal examination is done to check for staple-line bleeding at the anastomosis.

Antrectomy (Fig. 14)

The gastric antrum, along with other motionless intra-abdominal structures, may be surrounded so densely by tumor that resection rather than peritoneal stripping is required for complete tumor removal.[13] The right gastric artery is divided, and blunt dissection is used to separate the first portion of the duodenum from the pancreas. A stapler (Ethicon PLC 75, Cincinnati, OH) is used to close off and transect the duodenum just below the last visible evidence of tumor. Similarly a stapler (Ethicon TA 90, Cincinnati, OH) divides the stomach proximally above the tumor.

Gastric Reconstruction (Fig. 15)

The duodenal and gastric staple lines are inverted with interrupted sutures. A side-to-side gastrojejunostomy is performed. A large bore Malincott tube is secured through the side of the duodenum with purse-string sutures. Plication of the Malincott tube within the wall of the duodenum will prevent leakage around the tube.

Tubes and Drains Required for Early Postoperative Intraperitoneal Chemotherapy (Fig. 16)

Closed suction drains are placed in the dependent portions of the abdomen. This includes the right subhepatic space, the left subdiaphragmatic space, and the pelvis. A Tenckhoff catheter (Quinton spiral peritoneal catheter, Quinton Inc., Seattle, WA) is placed through the abdominal wall, positioned beneath the loops of small bowel. All transabdominal drains and tubes are secured with purse-string sutures at the peritoneal level. Right-angle thoracostomy tubes (Deknatel, Floral Park, NY) are inserted on both the right and left to prevent fluid accumulation in the chest as a result of intraperitoneal chemotherapy.

As soon as the abdomen is closed, irrigation of the abdomen with 1.5% dextrose dialysis solution (Dianeal, Abbott Laboratories, Chicago, IL) is begun. Standardized orders for early postoperative intraperitoneal lavage and for early postoperative intraperitoneal chemotherapy administration are instituted.[16]

DISCUSSION

An important concept in the modern treatment of malignancy is dose intensity.[22,23] In the strategy presented, the maximal effects of surgical cytoreduction are combined with maximal effects of chemotherapy cytoreduction at the same time and at the same anatomic location. This results in maximal dose intensity and treatment success in selected patients with peritoneal carcinomatosis. Surgical attempts to cure peritoneal carcinomatosis have never been successful in the past. Palliative attempts to remove even limited quantities of peritoneal carcinomatosis always have resulted in a rapidly recurring confluence of tumor within the abdominal cavity. Also, intraperitoneal chemotherapy alone has been singularly unsuccessfully in treating large volumes of intra-abdominal cancer. Only when the combined treatments are used have treatment successes been reported.

Six different peritonectomy procedures are reported that may be required for maximal surgical cytoreduction. It is unusual for all six of these procedures to be needed for a single patient if low-volume disease is being treated. When all six procedures are used, patients usually have grade 1 cystadenocarcinoma of ovarian, appendiceal, or colorectal origin. Also, mesothelioma patients may require all of the peritonectomy procedures.

The pelvic peritonectomy may be the most frequently performed procedure. It may be used in the treatment of primary ovarian malignancy with peritoneal spread. Also, advanced rectal and rectosigmoid colon cancers with full-thickness penetration of the bowel wall and peritoneal seeding in the pelvis should have a pelvic peritonectomy. If a large volume of grade 1 cancer is present within the abdomen the pelvis often has the largest volume of disease.

The right and left upper quadrant peritonectomy also is frequently required in appendiceal, colon, and ovarian cancer patients. Lymphatic lacuna (large peritoneal pores) exist on the undersurface of the diaphragms. These open lymphatic channels accept tumor cells into the superficial layer of the diaphragm's undersurface.[24,25] These tumor cells then grow as a sheet of cancer adherent to the undersurface of the hemidiaphragm. As tumor beneath the diaphragm progresses, this malignancy may involve the dome of right or left lobes of the liver. Complete removal of this tumor requires stripping of the undersurface of the diaphragm and a dissection of Glisson's capsule away from liver parenchyma.

Greater omentectomy usually is combined with splenectomy to achieve a complete cytoreduction. Of course, if the spleen is free of tumor, it is left *in situ.* The same is true when performing a lesser omentectomy. If the gallbladder is not involved by tumor, it can be preserved.

Perhaps the most difficult peritonectomy is the lesser omentectomy with stripping of the omental bursa. Vital structures here are of great density, and mistakes in dissection can lead to life-endangering hemorrhage or severe loss of function. The left gastric artery is the most commonly traumatized vessel. Its loss will result in the need for subtotal gastrectomy. Ligation of the coronary vein may cause gastric portal hypertension when all other venous drainage of the stomach is removed by dissection around this organ. The left hepatic vein or left inferior subphrenic vein are thin-walled and may be damaged inadvertently by sudden and unpredictable diaphragmatic contractions stimulated by electrosurgical dissection. The left gastric artery, if arising from the left hepatic artery, will be encased by tumor and tends to obscure clear visualization of the vena cava, crus of right hemidiaphragm, and origin of left gastric artery. Dissection just one plane too deep in the omental bursa may result in damage to the right renal vein because it crosses the floor of the omental bursa.

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