General principles and techniques
Definitions
Celiotomy is a surgical incision into the abdominal cavity; the term laparotomy often is used synonymously, although it technically refers to a flank incision. A sudden onset of clinical signs referable to the abdominal cavity (e.g., abdominal distention, pain, vomiting) is called an acute abdomen.

Preoperative Concerns
Celiotomy is performed for a variety of reasons; surgery may be indicated for diagnostic purposes, such as obtaining biopsy samples, or for therapeutic reasons. Many animals that undergo abdominal exploratory surgery have chronic disease, but in some patients emergency abdominal surgery must be performed because of acute clinical signs. Some conditions are life-threatening, such as gastric dilatation-volvulus, colonic perforation, or severe hemorrhage, and appropriate therapy must be started promptly. Conditions that require surgery must be differentiated from those that can be managed medically. Although obviously unnecessary surgery must be avoided, surgery cannot always be delayed until it is certain the patient will benefit from it.

The decision to operate is based on the history and physical examination findings, radiographic and ultrasonographic studies, and laboratory analyses. Physical examination can be unreliable in predicting the severity of abdominal trauma. The inaccuracy associated with examining patients with acute abdominal disease, particularly that associated with trauma, can be attributed partly to the patient’s condition at the time of examination and the delayed development of clinical signs that occurs with some injuries. Depressed or lethargic animals may not show pain during abdominal palpation. Clinical signs of hemorrhage often are not apparent immediately after trauma; delays of 3 to 4 hours between injury and the development of shock and collapse are common in patients with liver or spleen lacerations. For these reasons, animals that have suffered traumatic injuries should be closely observed for at least 8 to 12 hours. In most cases life-threatening hemorrhage becomes apparent before this time. However, animals with traumatic bile peritonitis can show no overt clinical signs for several weeks. Likewise, traumatic mesenteric avulsion is seldom associated with clinical signs until peritonitis subsequently develops, usually several days after injury. Sensitive diagnostic tests such as diagnostic peritoneal lavage may help identify patients with significant abdominal trauma before overt clinical signs develop.

NOTE ● Be aware that overt clinical signs associated with mesenteric avulsions or rupture of the biliary tract may not become evident for 1 to 2 weeks after injury.

Preoperative management of most animals undergoing exploratory laparotomy is
dictated by the underlying abdominal disease. General observations include noting the animal’s attitude and posture, temperature, respiratory rate and effort, and heart rate and rhythm. Auscultation, percussion, and palpation of the abdomen and a rectal examination also should be performed. Serial examinations are important to detect trends or deterioration in the patient’s status. An intravenous catheter should be placed for fluid and drug administration, and blood samples should be drawn. Useful initial blood work in an animal with acute abdomen includes hematocrit, serum total protein, serum glucose concentrations, complete blood count (CBC), platelet count, and blood urea nitrogen (BUN). Other laboratory tests, such as the serum biochemistry profile and clotting parameters, can be performed, depending on the animal’s condition and the suspected underlying disease. Urine may be collected by means of cystocentesis or catheterization for urinalysis. An indwelling urinary catheter may be used to quantitate urinary output if necessary. Abdominal radiographs may detect peritoneal fluid (i.e., uroabdomen, peritonitis) or abnormal accumulations of air. A recent study determined that the most common cause of peritoneal effusion in adult cats was neoplasia, whereas the most common cause in kittens was right-sided heart failure (Wright, Gompf, DeNovo, 1999). Animals with acute abdominal signs of uncertain cause should have diagnostic peritoneal lavage if radiographs are nondiagnostic. Electrolyte and hydration abnormalities should be corrected before surgery.

NOTE ● If you note free air in the abdominal cavity of an animal that has suffered a recent traumatic injury, consider exploratory surgery; this finding may indicate rupture or perforation of the gastrointestinal tract.

Anesthetic Considerations
The anesthetic management of animals with abdominal disease depends on the underlying disease. Young, healthy animals can be premedicated with an anticholinergic and opioid (i.e., oxymorphone, butorphanol, buprenorphine) and induced with thiopental, propofol, or a combination of diazepam and ketamine given intravenously to effect.

Antibiotics
The appropriate use of antibiotics in patients undergoing abdominal surgery depends on the underlying disease, the animal’s overall general health, and the length and type of surgical procedure. Surgeries of less than 1½ to 2 hours in which a contaminated, hollow viscus is not opened do not usually warrant prophylactic antibiotics.

Surgical Anatomy
The rectus sheath is composed of an external and internal leaf. The external leaf is formed by the aponeurosis of the external abdominal oblique muscle and a portion of the aponeurosis of the internal abdominal oblique muscle. The aponeurosis of the transversus abdominis muscle joins the external leaf near the pubis. The internal leaf consists of a portion of the aponeurosis of the internal abdominal oblique muscle, the aponeurosis of the transversus abdominis muscle, and the transversalis fascia. The internal leaf disappears in the caudal third of the abdomen where the aponeurosis of the internal abdominal oblique muscle joins the external leaf, leaving the caudal rectus abdominis muscle covered only by a thin sheet of transversalis fascia and peritoneum.
NOTE  ●  The linea alba is easier to locate near the umbilicus because it becomes narrower near the pubis.

Surgical Techniques
The abdomen generally is explored by means of a ventral midline incision. In most animals the entire abdomen, including the inguinal areas, and the caudal thorax should be prepared for aseptic surgery to allow extension of the incision into the thoracic or pelvic cavities if necessary. Prepping too small an area is a common mistake, particularly for abdominal exploration in trauma patients. To visualize all abdominal structures adequately, the incision must extend from the xiphoid process to the pubis. If only a specific abdominal structure is to be examined, a shorter incision can be made. A caudal abdominal incision that extends from the umbilicus to the pubis is adequate for bladder exploration; similarly, a cranial abdominal incision (i.e., umbilicus to xiphoid process) allows evaluation of the liver and stomach. Rarely, the midline incision is extended laterally at the xiphoid process (1 cm caudal to the last rib) to facilitate exposure of the liver, biliary system, and diaphragm. A paracostal (paralumbar) celiotomy can be used to expose the kidneys and adrenal glands; it is most commonly used for unilateral adrenalectomy.

NOTE  ●  Always count surgical sponges before making the incision and before abdominal closure to help ensure that none are inadvertently left in the abdominal cavity.

Ventral Midline Celiotomy in Cats
With the patient in dorsal recumbency, make a ventral midline skin incision beginning near the xiphoid process and extending caudally to the pubis. Sharply incise the subcutaneous tissues until the external fascia of the rectus abdominis muscle is exposed. Ligate or cauterize small subcutaneous bleeders and identify the linea alba. Tent the abdominal wall and make a sharp incision into the linea alba with a scalpel blade. Palpate the interior surface of the linea for adhesions. Use scissors to extend the incision cranially or caudally (or both) to near the extent of the skin incision. Digitally break down the attachments of one side of the falciform ligament to the body wall or excise it and remove it entirely if it interferes with visualization of cranial abdominal structures. Clamp the cranial end of the falciform ligament and ligate or cauterize bleeders before removing it.

Paracostal Celiotomy
Position the animal in lateral recumbency and place a rolled towel or sandbag between the animal and the operating table. Make a skin incision from the ventral vertebral column to near the ventral midline. Center the incision halfway between the wing of the ilium and the last rib. Extend the incision through the external abdominal oblique muscle with scissors. Separate internal abdominal oblique and transversus abdominis muscle fibers and expose the peritoneal and transversalis fascia. Tent the peritoneum and sharply incise it with scissors.

Abdominal Exploration
Systematically explore the entire abdomen.
Various techniques may be used; however, every surgeon should develop a consistent pattern to ensure that the entire abdominal cavity and all structures are visualized and/or palpated in each animal. Use moistened laparotomy sponges to protect tissues from drying during the procedure. If generalized infection is present or if diffuse intraoperative contamination has occurred, flush the abdomen with copious amounts of warmed, sterile saline solution.

Historically, many different antiseptics (i.e., povidoneiodine, chlorhexidine) and antibiotics have been added to lavage fluids. Povidone-iodine is the most widely used antiseptic; however, this practice has not shown a beneficial effect in repeated experimental and clinical trials and may be detrimental in animals with established peritonitis because the carrier, polyvinylpyrrolidone, inhibits macrophage chemotaxis. Similarly, there is no substantial evidence that adding antibiotics to lavage fluid benefits patients treated with appropriate systemic antibiotics.

Remove the lavage fluid and blood and inspect the abdominal cavity before closure to ensure that all foreign material and surgical equipment have been removed. Perform a sponge count and compare it with the preoperative count to ensure that surgical sponges have not been left in the abdominal cavity.

Abdominal Wall Closure
The linea alba may be closed with a simple continuous or a simple interrupted suture pattern. The simple continuous technique does not increase the risk of dehiscence when properly performed (i.e., secure knots, appropriate suture material, adequate bites in the rectus sheath), and it allows for rapid closure. Preferably strong, synthetic absorbable suture material (i.e., polydioxanone, polyglyconate, poliglecaprone 25) should be used for continuous suture patterns, and six to eight knots should be placed at each end of the incision line. Surgical gut and stainless steel wire should not be used for continuous suture patterns.

On each side of the incision, incorporate 5 to 7 mm of fascia in dogs and 3 to 5 mm in cats in each suture. Place abdominal wall sutures no further apart than 3 to 4 mm, depending on the animal’s size. Tighten sutures sufficiently to appose but not enough to strangulate tissue, because sutures that strangulate tissue negatively affect wound healing. Incorporate full thickness bites of the abdominal wall in the sutures if the incision is midline (i.e., through the linea alba). Do not incorporate the falciform ligament between the fascial edges. If the incision is lateral to the linea alba and muscular tissue is exposed (i.e., paramedian incision), close the external rectus sheath without including muscle or peritoneum in the sutures. Close subcutaneous tissues with a simple continuous pattern of absorbable suture material and reappose the preputialis muscle fibers in the male dog. Use nonabsorbable sutures (simple interrupted or continuous appositional pattern) or stainless steel staples to close skin. Place skin sutures without tension.

Healing of the Abdominal Wall
The ability of tissues to hold sutures without tearing depends on the tissue’s collagen density and the orientation of collagen fibrils. Skin and fascia are strong, whereas muscle
and fat are weak. Peritoneum heals rapidly across the incision and does not contribute to wound strength, therefore closure of this layer is not beneficial. Experimental and clinical studies in dogs suggest that suturing peritoneum may increase the incidence of postoperative intraabdominal adhesions.

**NOTE**  •  Make sure to incorporate fascia in the linea closure. Because the holding layer of abdominal incisions is collagen dense fascia rather than muscle, dehiscence is common if the rectus fascia is not incorporated in sutures.

**SUTURE MATERIALS AND SPECIAL INSTRUMENTS**

Useful instruments for celiotomy include Balfour abdominal retractors, Poole or Yankauer suction tips, malleable retractors, and Mixter (right-angle) forceps. Laparotomy pads and 4 × 4 sponges should have radiopaque markers.

**Postoperative Care and Assessment**

The abdominal incision should be checked twice daily for redness, swelling, or discharge. If the animal licks or chews at the incision, an Elizabethan collar or sidebar should be used to prevent iatrogenic suture removal. Early signs of altered wound healing are inflammation and edema. Serosanguineous drainage from the incision and swelling are consistent signs of acute incisional dehiscence. Dehiscence usually occurs 3 to 5 days after surgery, when minimal healing has occurred and the sutures have weakened; however, it may occur earlier if knots were tied improperly or if fascia was not incorporated into the sutures. Evisceration usually results in sepsis and severe blood loss secondary to mutilation of exposed intestine and must be treated promptly. The abdomen should be bandaged, fluid therapy initiated, and broad-spectrum antibiotics given while the animal is prepared for surgery. If technical failure is suspected, such as poor knot tying or improper suturing, the entire suture line should be removed and replaced. Debridement of the wound edges is unnecessary and delays wound healing. The intestine should be closely inspected for viability and damaged sections resected if appropriate. The abdominal cavity should be lavaged copiously with warmed, sterile saline. Open abdominal drainage should be considered in animals with generalized peritonitis. Wound disruption after 10 to 21 days usually results in hernia formation rather than evisceration. Hernial repair in these animals may require excision of fibrotic tissues. Subsequent closure requires that tissue layers be accurately apposed.

**Complications**

Dehiscence (incisional hernias) may occur if improper surgical technique is used (see the above discussion). The most common causes of wound dehiscence in the early postoperative period are suture breakage, knot slippage or untying, or sutures cutting through tissue. A higher rate of dehiscence may be seen in animals with wound infections, fluid or electrolyte imbalances, anemia, hypoproteinemia, metabolic disease, immunosuppression (e.g., feline immunodeficiency virus [FIV], feline leukemia virus), or abdominal distention or in those that have been treated with corticosteroids, chemotherapeutic agents, or radiation. Suture sinus formation has been reported with nonabsorbable suture material. Such cases require surgical resection of affected tissues and removal of offending sutures.
Special Age Considerations
Healing may be delayed in debilitated, very young or very old, or hypoproteinemic animals; chromic gut suture should not be used for abdominal wall closure in these patients.

TRAUMATIC ABDOMINAL WALL HERNIAS
Definitions
External abdominal hernias are defects in the external wall of the abdomen that allow protrusion of abdominal contents; internal abdominal hernias are those that occur through a ring of tissue confined within the abdomen or thorax (i.e., diaphragmatic hernia, hiatal hernia). External abdominal hernias may involve the abdominal wall anywhere other than the umbilicus, inguinal ring, femoral canal, or scrotum.

Synonyms
Abdominal hernias may be defined according to their location (i.e., ventral, prepubic, subcostal, hypochondral, paracostal, or lateral). The cranial pubic ligament formerly was called the prepubic tendon.

General Considerations and Clinically Relevant Pathophysiology
Abdominal hernias generally occur secondary to trauma, such as vehicular accidents or bite wounds; however, they occasionally have been reported as congenital lesions. Congenital cranial abdominal hernias (i.e., cranial to the umbilicus) have been reported in association with peritoneopericardial diaphragmatic hernias in dogs and cats. Abdominal hernias are false hernias because they do not contain a hernial sac. When associated with blunt trauma, they arise as a result of rupture of the wall from within caused by an increase in intraabdominal pressure while the abdominal muscles are contracted. The most common sites for traumatic abdominal hernias are the prepubic region and the flank. Cranial pubic ligament hernias often occur in association with pubic fractures. Paracostal hernias may result in migration of abdominal contents along the thoracic wall. In rare cases the abdominal contents enter the chest through defects in the intercostal muscles.

Diagnosis
Clinical Presentation
Signalment. Most animals with abdominal hernias are young.
History. A history of trauma is common with abdominal hernias. The hernia initially may be overlooked while more obvious or life-threatening injuries are treated. If strangulation or intestinal obstruction occurs, the animal may be presented for treatment of vomiting, abdominal pain, anorexia, and/or depression.

Physical Examination Findings
Abdominal structures (i.e., organs or omentum) in the subcutaneous space or between muscle layers usually cause asymmetry of the abdominal contour. The size of the swelling may not correspond to the size of the hernia, particularly if intestine has migrated into the hernia. The swelling should be palpated carefully to discern the contents of the hernia (i.e., intestine, bladder, or spleen) and to locate the abdominal
defect. These patients should be thoroughly examined to determine whether a concurrent abdominal or thoracic injury or abnormality exists. Rupture of the cranial pubic ligament often is difficult to palpate because of subcutaneous swelling and pain.

Radiography and Ultrasonography
Radiographs should be taken in animals with abdominal hernias. Routine ventral dorsal and lateral views may show an associated abdominal or thoracic injury (e.g., abdominal fluid, diaphragmatic hernia). Abdominal radiographs may help confirm the presence of a hernia (i.e., subcutaneous intestinal loops and loss of the ventral abdominal stripe) when the abdominal wall defect cannot be palpated because of swelling or pain. Ultrasound scans may also help define the contents of hernias.

Laboratory Findings
Abnormalities associated with abdominal hernias vary depending on the severity of concurrent internal injuries.

Differential Diagnosis
Most hernias are diagnosed on physical examination. Differential diagnoses for abdominal swellings include abscesses, cellulitis, hematomas or seromas, and neoplasia.

Medical Management
Initial treatment of animals with abdominal hernias is directed toward diagnosing and treating shock and concurrent life-threatening internal injuries.

Surgical Treatment
Patients that sustain a traumatic injury severe enough to cause an abdominal hernia or patients that sustain penetrating abdominal wounds (i.e., gunshot, bite wounds) should have a xyphoid to pubis abdominal exploratory laparotomy. All visceral structures should be carefully examined to signs of trauma (e.g., mesenteric rents, ruptured hollow viscous organs, avulsed kidney, ureteral damage). In addition, abdominal celiotomy approach facilitates abdominal hernia closure. Most abdominal hernias can be repaired by suturing torn muscle edges or apposing the disrupted abdominal wall edge to the pubis, ribs, or adjacent fascia. In rare cases synthetic mesh must be used to repair the defect. Some hernias (i.e., intestinal strangulation, urinary obstruction, concurrent organ trauma) require emergency surgical correction. However, the extent of devitalized muscle may not be apparent initially, and in patients in stable condition, delaying surgery until muscle damage can be accurately assessed facilitates surgical correction. The most common complications of surgery are hernia recurrence and wound infection. Abdominal hernias that occur secondary to bite wounds usually are contaminated; wound infection and dehiscence of the skin or hernial repair (or both) may occur. Mesh should not be placed in these hernias, hernial closure is performed during exploratory laparotomy, and the skin wounds should be left open to drain. Treatment of infected wounds includes cultures, drainage, antibiotics, and/or flushing.

Preoperative Management
Preoperative care depends on the animal’s status and concurrent injuries. Hydration and electrolyte abnormalities should be corrected before surgery.

Anesthesia
If there are no concurrent abdominal injuries or disease, a variety of anesthetic protocols can be used to anesthetize the animal. However, the presence of underlying disease may dictate the anesthetic management of sick or debilitated patients.

Surgical Anatomy
The abdominal wall is composed of four muscle layers (the external and internal abdominal oblique muscles, the rectus abdominis muscle, and the transversus abdominis muscle). Abdominal hernias may occur at insertions or attachments of these muscles or through muscle bellies themselves. The cranial pubic ligament (prepubic tendon) is a band of transverse fibers that connects the ilipectineal eminence and pectineal muscle origin of one side with those on the other side. This ligament attaches the rectus abdominis muscle to the pelvis.

Positioning
For ventral hernias the animal is placed in dorsal recumbency and the area around the hernia is prepared for aseptic surgery. Repair of ruptures of the cranial pubic ligament may be facilitated by placing the animal in dorsal recumbency with the rear limbs flexed and pulled cranially.

Surgical Techniques
Abdominal Hernias
For most abdominal hernias, perform a ventral midline abdominal incision to allow the entire abdomen to be explored. Assess the extent of visceral herniation. Reduce the herniated contents and amputate or excise necrotic or devitalized tissue around the hernia. Close the muscle layers of the hernia with simple interrupted or simple continuous sutures. If a large area of devitalized tissue is removed, use synthetic mesh such as Marlex or Prolene to close the defect (do not place mesh in infected sites). Fold the edges of the mesh over and suture the folded edges to viable tissue using simple interrupted sutures. Injuries to the cranial pubic ligament can be difficult to repair. If necessary, drill holes in the pubic bone to anchor the sutures.

Paracostal hernias. Make a midline abdominal incision. Explore the hernia and suture the torn edges of the transverse, internal, and external abdominal oblique muscles. Incorporate a rib in the suture if muscle has been avulsed from the costal arch.

Cranial pubic ligament hernias. Make a ventral midline skin incision and identify the ruptured tendon and its pubic insertion. Evaluate the inguinal rings and vascular lacuna; these hernias may extend into the femoral region as a result of rupture of the inguinal ligament. Reattach the free edge of the abdominal wall to the cranial pubic ligament with simple interrupted sutures. As an alternative, suture the tendon remnant to the muscle fascia and periosteum covering the pubis or anchor it to the pubis by drilling holes in the pubic bone through which sutures can be placed. If the hernia extends into the femoral
region, it may be necessary to suture the body wall to the medial fascia of the adductor muscles. When doing so, take care to avoid damaging the femoral vessels or nerves.

Suture Materials and Special Instruments
Strong, absorbable suture (polydioxanone, polyglyconate, poliglecaprone 25) or nonabsorbable suture (polypropylene or nylon) should be used to repair abdominal or ventral hernias. Marlex and Prolene synthetic mesh may be used to repair some large defects.

Postoperative Care and Assessment
The postoperative care of these patients is dictated by the presence of concurrent injuries or disease. The patient should be kept quiet, and the wound should be checked frequently for infection or dehiscence. Vomiting, fever, and/or leukocytosis may indicate peritonitis.

Prognosis
The prognosis generally is good, and recurrence is uncommon. When recurrence occurs, it generally is noted within a few days of surgery. Most animals have excellent long-term results when appropriate techniques are used.