Intraabdominal Sepsis

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Sepsis continues to be the primary cause of late death in the multiply injured patient. The diagnosis and management of intraabdominal sepsis (IAS) in these patients can be most challenging. IAS can be caused by a localized process (e.g., nonvisceral abscess, cholecystitis, visceral abscess, infected hematoma) or a nonlocalized process (generalized peritonitis). Although most patients with IAS will have had a celiotomy for their initial injuries, some may not (e.g., those with acute cholecystitis or acute pancreatitis). The mortality rate of patients whose intraabdominal abscesses (IAA) have been drained is as high as 40%; however, recent reports note mortality rates less than 20% because of better critical care, better diagnostic imaging, and earlier diagnosis and treatment. Trauma contributes to only a minority of the total cases of IAA. Altemeier et al.[1] reported only 17 (3%) trauma patients of 500 cases of IAA. At the Shock Trauma Center of the Maryland Institute for Emergency Medical Services Systems (MIEMSS), we saw 119 patients with IAA in 5000 admissions for multiple trauma.[2]

Etiology

The reported incidence of IAS after penetrating abdominal trauma ranges from 3% to 50%, with the highest incidences associated with gastrointestinal perforation and gunshot wounds. Other risk factors associated with IAA formation include advanced age, shock, the recovery of bacteria from the peritoneal cavity at the initial operation, a high transfusion requirement, multiple organ injury, the need for colostomy, the length of operation, and the combination of colonic and pancreatic or duodenal injury.[3,4] The use of antibiotics in the perioperative period has been shown to decrease the postoperative infection rate. Although most agree that irrigation of the peritoneal cavity decreases the bacterial load, the effectiveness of reducing infection by adding antibiotics to the irrigant is still unsettled.

IAA after blunt abdominal trauma is not as common as with penetrating trauma. In a review of a 2½-year period in which 325 MIEMSS patients required emergency laparotomy for blunt abdominal trauma, 15 (4.6%) had postoperative IAA. All patients had at least one extraabdominal associated injury, most commonly involving the chest, pelvis, or brain. The most common intraabdominal injuries associated with IAA were spleen and liver injuries.

Intraabdominal sepsis is second to exsanguination as the leading cause of death resulting from liver trauma and is the primary cause of late death. Scott et al.[5] reported that the blood transfusion requirement was the most important determinant in abscess formation in their series, where IAA occurred in 17% of patients. The need for hepatic resection or hepatic packing to control hemorrhage, associated gastrointestinal tract injury, and open drainage systems have all been implicated in the formation of IAA.

IAS may result from gastrointestinal anastomotic breakdown sustained from either blunt or penetrating abdominal trauma, producing either a localized abscess and fistula or generalized peritonitis. Blunt intestinal injuries can be missed because of a false-negative peritoneal lavage or computed tomographic scan (CT). Delayed rupture of bowel because of a bowel wall contusion, and ischemia caused by a mesenteric hematoma are rare causes of IAS.[6] Patients who have posttraumatic acute pancreatitis may have with signs of IAS, although fewer than 10% of them will have pancreatic necrosis or abscess formation requiring surgical drainage.

Acute acalculous cholecystitis is another rare entity occurring in the posttraumatic critically ill patient (see Cornwell et al., page 346). Only 0.5% of 2000 critically ill patients had this complication at our institution.[7] Intraabdominal infection resulting from an open pelvic fracture is a rare but potentially lethal complication in these patients who have already survived the threat of exsanguination. An open pelvic fracture is defined as a pelvic ring disruption associated with a break

Risk factors associated with intraabdominal abscess formation

- Penetrating abdominal trauma
- Advanced age
- Shock
- Bacteria in peritoneal cavity at initial operation
- High transfusion requirement
- Multiple organ injury
- Need for colostomy
- Prolonged length of operation
- Combination of colonic and pancreatic or duodenal injury
- Need for hepatic resection or packing to control hemorrhage
- Associated gastrointestinal injury
- Open drainage systems
- Delayed rupture of bowel caused by wall contusion
- Ischemia resulting from mesenteric hematoma
- Acute acalculous cholecystitis
- Open pelvic fracture
- Hematoma (intraperitoneal or retroperitoneal)
- Transient bacteremia

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77/1/20291

CRITICAL CARE REPORT 1990;1:352-358

in the epithelial barrier such as an associated perineal wound, a ruptured urinary bladder or urethra, or a rectal injury. This break in the epithelium provides an avenue by which organisms from infected urine or stool may contaminate any associated pelvic hematoma. Patients with an intraperitoneal hematoma or a retroperitoneal hematoma are also at risk of secondary bacterial seeding by infection associated with an intravascular or genitourinary catheter, causing bacteremia. Altemeier et al.[1] could not identify a primary source of infection in 9% of their patients with IAA, indicating that a transient bacteremia may have some role in the formation of cryptogenic IAA. A rushed or inadequate abdominal skin preparation preceding an urgent laparotomy may also increase the risk of intraabdominal contamination.

Presentation

Most patients with IAS initially have an elevated white blood cell count, an elevated temperature, and an increased heart rate. These nonspecific signs are also present in most patients after surgery who are not infected. The clinical presentation depends on whether the abdomen can be examined reliably. Physical examination may help in the diagnosis of IAA in as many as 40% to 60% of patients without organ failure or neurologic dysfunction.[8] The presence of an ileus (abdominal distension, decreased bowel sounds, high nasogastric output), abdominal tenderness, an abdominal mass, or abnormal drainage from a wound or drain site suggests IAS. Frank generalized peritonitis mandates an emergency celiotomy without the need for further workup. A rectal examination may uncover a pelvic abscess amenable to transrectal drainage.

Other patients with IAS may have severe brain or spinal cord injuries or multiple organ dysfunction; in this group, physical examination may not be helpful. Most of these patients have sustained severe injuries to the abdomen or to multiple systems. Because examination of the abdomen can be unreliable, these patients are at high risk for clinical deterioration because of an occult intraabdominal focus of infection. This delay in diagnosis may lead to organ failure as a mode of presentation. By the time these patients are seen with multiple organ system failure (MOSF), stress and instability are further developed and their mortality rate is higher. Why some patients present in this manner is unknown, but the reason may be related to an overwhelming infectious challenge in a patient who is maximally stressed because of severe trauma and whose immune system is already compromised. MOSF is defined as the failure of two or more organ systems, as demonstrated by a rising serum creatinine level, ventilator dependence with a fraction of inspired oxygen (FIO_2) ≥40%, abnormal results of liver function test and bilirubin level, inability to be fed enterally, gastrointestinal bleeding, and dependence on inotropic support to maintain cardiovascular function.

Other nonspecific physical findings associated with sepsis include tachypnea, hypothermia, icterus, agitation, confusion, and lethargy. Increased fluid requirements, suggesting decreasing vascular tone and increasing "third-space" fluid content, are part of the septic profile. Laboratory abnormalities seen in these patients include thrombocytopenia, hyponatremia, hypernatremia, hypertriglyceridemia, hyperglycemia, coagulopathy, azotemia, leukopenia, and lactic acidosis. The presence of multiple enteric organisms cultured from the blood was associated with an intraabdominal source of sepsis in 78% of cases in the series of Ing et al.[9]

Hemodynamic-cardiovascular monitoring has become standard in critical care units and commonly leads to the early detection of sepsis in these ill patients. The early septic state is usually associated with tachycardia, low pulmonary artery occlusion pressures, normal or high cardiac output, and a decrease in systemic vascular resistance. Oxygen consumption may be low with inadequate intravascular volume support and usually reveals a hypermetabolic state with adequate volume loading. The value of close hemodynamic monitoring is early recognition of the septic state and subsequent support before the cascade of altered tissue perfusion leading to multiple organ failure supersedes.

Investigations

Routine plain radiographs of the chest and abdomen demonstrate nonspecific signs of IAS in about 50% of cases.[10] The chest x-ray film may show lower lobar atelectasis, pleural effusions, or elevation of the hemidiaphragm. Abdominal x-ray films may demonstrate bowel displacement, extraluminal air, or obliteration of fat margins in the retroperitoneum. Plain films can only support the clinical diagnosis: the absence of findings does not rule out IAS. Abnormal plain films are not specific enough to confirm or define the location of an intraabdominal septic source; therefore, other studies may be indicated before therapy is instituted. The use of contrast gastrointestinal studies with either water-soluble meglumine diatrizoate (Gastrografin) or barium is helpful when perforation of the gastrointestinal tract or leakage of a suture line is suspected. Barium may interfere with additional studies such as CT or ultrasonography.

We rely on ultrasound and CT to confirm the diagnosis of an intraabdominal collection, which may afford radiographic guidance for needle aspiration for diagnosis and percutaneous catheter drainage for treatment (Fig. 1). Sonographic localization of intraabdominal collections is best when they are near solid organs (liver, spleen, kidney) and a sonic window can be used as a reference. The pelvis is also a good location because a fluid-filled bladder provides such a window.

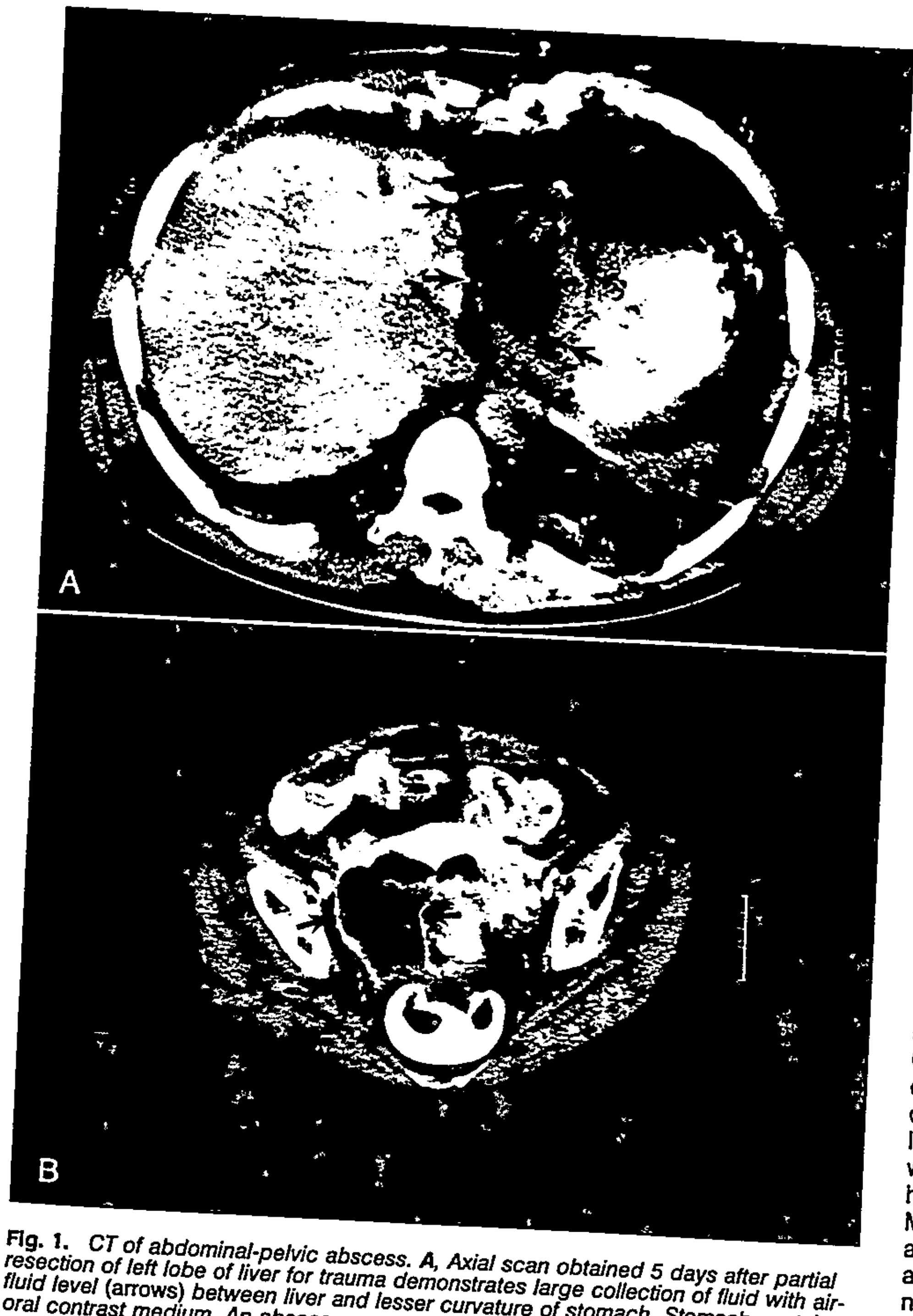

Fig. 1. *CT of abdominal-pelvic abscess. **A**, Axial scan obtained 5 days after partial resection of left lobe of liver for trauma demonstrates large collection of fluid with air-fluid level* (arrows) *between liver and lesser curvature of stomach. Stomach contains oral contrast medium. An abscess was surgically drained. **B**, Axial CT scan through pelvis obtained in patient with sepsis demonstrates large fluid and gas collection* (arrows) *to right of rectum. No contrast material is seen within collection. At surgery, collection proved to represent an abscess.*

Accuracy rates higher than 90% have been reported. The advantages of ultrasonography in critically ill patients are its noninvasiveness and the ability to do the study within minutes at the bedside, eliminating the risk of transporting these patients, who are often ventilator dependent and have multiple intravenous drips.

Findings on sonographic examination consistent with abscess include oval hypoechoic fluid collections or collections with multiple low-level internal echoes. No specific signs of abscess exist; therefore, clinical correlation must be considered. If such a collection is identified, percutaneous needle aspiration can confirm the diagnosis. Normal coagulation systems and an access that does not traverse a hollow viscus ensure safe aspiration. Ultrasound evaluation can also identify intrahepatic abscesses and acute cholecystitis of either calculous or acalculous origin. However, ultrasonography has drawbacks in patients with an ileus. Complicated abdominal wounds and multiple drain sites may also interfere with testing. Abscesses in the postsplenectomy left subphrenic area and those of the interloop variety are also assessed poorly by sonographic evaluation.

When contrast is used, CT enjoys accuracy rates as high as 97% for collections greater than 2 cm in diameter. We use CT in all patients suspected of harboring an intraabdominal source of sepsis when physical examination is equivocal. CT overcomes the drawbacks of sonographic assessment except in the evaluation of interloop abscesses. The main drawback for CT is the risk of transporting these critically ill patients to the radiology department. The finding of air-fluid levels or gas stippling associated with intraabdominal collections is highly specific for IAA but rare. More common CT findings include a round, well-defined, low-attenuation mass that may displace nearby organs and may be associated with surrounding edema highlighted by intravenous contrast. Infected serous fluid may have Hounsfield units ranging from 0 to 20, pus will range between 20 and 40 U, and hematomas will range up to 90 Hounsfield units. Once a collection is identified, the diagnosis of abscess can be confirmed by either sonographic- or CT-guided needle aspiration if it is accessible in a

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safe manner. If possible, hematomas seen on CT should be aspirated to check for bacterial invasion, as should phlegmons. Needle aspiration may be withheld when the procedure would be risky (e.g., if hollow viscus or major vessels are nearby), if the patient is stable and can be observed clinically for deterioration. CT evaluation is also important in the diagnosis of acute acalculous cholecystitis: this disorder is suspected when the gallbladder wall is greater than 4 mm, when pericholecystic fluid is present in the absence of ascites, or intramural gas or a sloughed mucosal membrane of the gallbladder is present (see Cornwell et al., page 346).

To develop an abscess detectable by CT may take a week. Any evaluation before that time may pick up only normal postoperative changes; therefore, CT should be done 1 week after surgery in patients suspected of harboring an IAA. The role of nondirected CT in assessing critically ill patients with MOSF who have minimal signs referable to an abdominal process is less clear. Most investigators have found this tool to be of little value. Ivatory et al.[4] showed that nondirected CT was helpful in only 12.5% of patients who had IAA with MOSF caused by penetrating trauma compared with 93% of patients without MOSF. Norwood and Civetta[11] had a similar experience in their analysis of CT in surgical intensive care unit patients. They suggest that CT be used to confirm clinical diagnosis for the best yield.[11] The benefit of nondirected CT must be weighed against the cost and risk of transporting these ill patients.

The role of other imaging techniques is less defined in the posttraumatic critically ill patient with possible IAS. These patients are usually too sick to transport to the radiology department for fluoroscopy, where the yield is usually low. Magnetic resonance imaging is still new to most centers. Radionuclide scintigraphy using white blood cells labeled with either gallium 67 or indium 111 has yielded accuracy rates greater than 85% in localizing and identifying IAA. The use of scintigraphy is presently limited to stable patients with occult sepsis, because obtaining a positive scan may take 3 days. Sometimes CT can be used to take finer cuts in those suspicious areas seen on scintigraphy for better identification of fluid collections.

Nondirected exploratory celiotomy still has a role in the patient with sepsis and progressive organ dysfunction in whom an intraabdominal source is suspected, although physical examination is inconclusive because of either medications or neurologic dysfunction. Intraabdominal sepsis was responsible for MOSF in 44% of a series of 38 patients who underwent receliotomy, described by Fry et al.[12] Polk and Shields[13] reported improvement of organ dysfunction after the surgical drainage of such foci. Ferraris[14] found that 80% of his 29 patients who had new-onset single-organ failure or worsening MOSF after surgery had an intraabdominal source of infection as its cause. Hinsdale and Jaffe[15] examined 11 patients solely for MOSF and found drainable collections of pus in six (55%). Four of these patients had negative radiographic studies. The authors concluded that, in patients with MOSF, a high index of suspicion for an intraabdominal source of sepsis is warranted. The survival rate for those without and with drainable sources of infection was 18% and 33%, respectively.[15] Bunt[16] thought that, although the yield was low for nondirected celiotomies in critically ill patients with MOSF, the procedure was well tolerated by the young trauma patient and probably should be avoided in the elderly. He reported an overall positive celiotomy rate of 63% in patients with MOSF. Those patients undergoing directed celiotomies had a 94% positive celiotomy rate, whereas only 13% of those with nondirected celiotomy had positive findings. In the series of Sutherland et al.[17] of 80 patients with MOSF, the positive nondirected celiotomy rate was 59%.

Exploratory celiotomy is the most efficacious diagnostic maneuver for patients with signs of sepsis and new-onset organ dysfunction within a week after surgery; it is potentially therapeutic. These cases must be managed aggressively before the onset of MOSF. Norton[18] concluded that MOSF caused by IAS carries a high mortality (76%) and that surgical drainage will not reverse organ failure in the majority of patients. Autopsy examinations of the 16 patients who died demonstrated a persistent focus of infection in only three (19%). Perioperative mortality rates in patients with sepsis and MOSF undergoing receliotomy range from 70% to 90% regardless of whether a septic focus is found.[4,15,16,19]

Location

An intraabdominal septic focus can be in an intravisceral, extraperitoneal, or intraperitoneal location. Intrahepatic abscesses are the most common intravisceral IAA (13% of cases) resulting from trauma or any other cause.[2,20] Pancreatic abscesses are the second most common, with splenic abscesses and acute cholecystitis being less common. When looking at all cases of IAA from all causes, extraperitoneal locations constitute 12% to 38% of the total, equally divided between the anterior and posterior retroperitoneum. Intraperitoneal locations account for 36% to 76% of IAA.[1,19,20] The location of intraperitoneal collections varies with each series, depending on whether appendicitis or diverticulitis was included; generally, they are equally distributed among the pelvis, pericolic, and subphrenic areas. Intraperitoneal abscesses tend to form in dependent areas such as the pelvis or in the subphrenic area, because of the cephalad flow of peritoneal fluid. Intraabdominal collections caused by trauma are located in the upper quadrants in the majority of cases. Seventy-five percent of IAA cases resulting from penetrating trauma in the patients of Ivatory et al.[4] were located in the upper quadrants. In a group of MIEMSS patients with IAA after blunt abdominal trauma, 62.5% of collections were located in the upper quadrants. Other less common sites of intraperitoneal sepsis include generalized peritonitis and lesser sac, pelvic, and interloop collections.

Management

Whenever an intraabdominal source of sepsis is suspected, prompt surgical evaluation and intervention are required. The mortality from undrained IAA approaches 100%, and any delay in treatment predisposes the patient to the risk of organ failure. Critically ill patients may require ventilatory support for the increased oxygen demand caused by sepsis. Tissue oxygen delivery depends on an optimal cardiac output (sometimes requiring inotropic support) and an adequate hemoglobin concentration and blood volume.

Empiric broad-spectrum antibiotic therapy should be started when the diagnosis is suspected, while localization and drainage procedures are being planned. Generally, at least two or three organisms are isolated from intraabdominal abscesses; this polymicrobial picture is consistent with gastrointestinal flora. Anaerobes make up at least 50% of the organisms isolated when proper culture techniques are instituted. *Bacteroides fragilis* is the most common type of anaerobic organism found. Gram-negative rods remain the most common type of organism seen, with *Escherichia coli* predominating. *Aerobacter, Klebsiella, Pseudomonas,* and *Proteus* organisms contribute. In patients exposed prophylactically to some of the cephalosporins, enterococci have been isolated in subsequent abscesses but usually with another organism. Their role as a real pathogen in IAS remains unsettled. Antibiotic therapy should cover all organisms isolated from the blood or abscess cavity by Gram's stain, cultures, or both.

These critically ill patients usually must be treated empirically until the focus of infection is localized and drained. A third-generation cephalosporin or penicillin in combination with an aminoglycoside is most often used. Additional anaerobic coverage is provided by either clindamycin or metronidazole unless one of the new penicillins is already giving adequate coverage. Occasionally, a *Candida* species is isolated from IAA, which may require amphotericin B therapy.

Although antibiotics may retard the spread of infection and transiently lessen the systemic effects of sepsis on the various organ systems, drainage is the key to a successful outcome. With the advent of CT and sonographic localization of intraabdominal septic collections, radiographically guided percutaneous drainage (PD) has become the treatment of choice when applicable, with a success rate ranging from 78% to 90% in selected patients and with a low morbidity. Initially, CT drainage was used in patients with unilocular collections accessible percutaneously in a dependent manner if possible, without traversing any viscus organ. This technique met with early resistance because of the reported incidence of multiple abscesses found in 10% to 30% of patients undergoing laparotomy. Inadequately drained abscesses are associated with a high morbidity and mortality in those patients requiring a second operation. Gerzof et al.[21] demonstrated an 8% incidence of multiple abscesses in their series, with successful PD in 78% of them. They not only expanded the PD criteria to include those with multiple abscesses but also included those abscesses associated with enteric fistulas. Approximately 50% of patients with IAA will be candidates for PD.[20] Radiographic localization of IAS in patients with MOSF is often inconclusive, precluding any major role for percutaneous catheter drainage in these patients.

Surgical drainage of an IAA can be either extraperitoneal or transperitoneal. Extraperitoneal drainage enjoys the same low morbidity seen in PD techniques but also accepts the possible risk of missing other associated abscesses. Drainage should be dependent. Candidates for surgical drainage include:

- Patients with relative contraindications for PD drainage (multiloculated abscesses, multiple abscesses, absence of a safe percutaneous approach, and coagulopathy)
- Patients in whom the collection consistency is too thick for catheter drainage (fungal infections, infected hematomas, and pancreatic abscesses)
- Patients in whom previous PD attempts have failed
- Patients with an uncontrolled enteric fistula and generalized peritonitis
- Patients in whom an intraabdominal source of sepsis is suspected but cannot be localized radiographically

Closed drainage systems (for example, the large-caliber, soft, triple-lumen sump with bacterial filter) are commonly used. Removal of the twelfth rib posteriorly to drain hepatic-perihepatic abscesses may be useful. Pelvic abscesses close to the rectum or vagina can be localized with a needle and then drained dependently via those organs. The success rates after surgical drainage are similar to that of PD catheter drainage (75% to 90%). The morbidity and mortality rates are also similar. Patients should improve or stabilize within 24 to 48 hours after drainage by either PD or surgical means, as suggested by their overall clinical condition and by a decreasing white blood cell count and temperature; otherwise, insufficient drainage should be considered. Some patients may have severe neurologic dysfunction or concomitant extraabdominal sources of infection; an exercise in patience might be appropriate in these situations. If PD is deemed inadequate, surgical exploration and drainage should be undertaken before progressive organ dysfunction begins.

Mortality

The mortality rate after IAA drainage is reported to be as high as 30%. Since the advent of improved radiologic localization by ultrasonography and CT, the mortality rate has decreased to as low as 17%.[8,20] Improved survival has also been attributed to better resuscitation and support in critical care units. Early use of CT in patients suspected of having IAA has identified abdominal collections, which can be sampled and drained in a timely manner. PD and surgical drainge procedures have similar initial success rates, morbidity rates, and mortality rates. PD may have a higher initial successful drainage rate for subphrenic collections.[20] Fry et al.[22] identified seven determinants associated with a high mortality from IAA: organ failure, lesser sac abscess, subhepatic abscess, recurrent or persistent abscess, multiple abscesses, age greater than 50 years, and positive blood cultures. Repeat celiotomy for IAS and nondireted celiotomy are also associated with higher mortality. Failure of three organ systems carries a mortality rate greater than 75%.

MIEMSS Approach: Documented or Suspected IAS

Our approach to IAS in critically injured patients varies with their presentation. Any patient with frank peritonitis should have exploratory surgery without an extensive workup. In patients who appear to have sepsis but whose presentation is less acute with mild or no abdominal tenderness, a preoperative evaluation should be done. Victims of blunt abdominal trauma who have not had previous exploration done because of a normal CT or peritoneal lavage result may have signs of intraabdominal sepsis, ischemic bowel, or bowel perforation and must be assessed by standard contrast studies, CT with contrast, or exploratory celiotomy. Acute acalculous cholecystitis may occur in patients who may or may not have undergone exploratory surgery during treatment of the initial injury. This rare but potentially fatal condition is common in patients with severe brain injuries and in those heavily sedated and receiving mechanical ventilation. CT examination with or without sonographic collaboration will help make the diagnosis. Because of the ischemic component in the pathophysiology of this disease, cholecystectomy is the preferred therapy. (See Cornwell et al., page 346).

In patients who have undergone celiotomy for trauma, clinical sepsis rarely presents within the first 48 hours after surgery. An infectious focus may become localized and controlled by antibiotics until radiographic localization can be done. Because the usual intraperitoneal postoperative fluid collections cannot be distinguished from septic collections, sonographic and CT scan evaluations are not helpful until after the first week after surgery. If an anastomotic leak is suspected, contrast studies with Gastrografin may be done during the first week. One group of patients manifests the signs of early sepsis and progresses to organ dysfunction or failure within the first week after surgery: they have either multiple injuries that overwhelm their resistance to infection or a large bacterial challenge such as an anastomotic leak. For these patients, one must adopt an aggressive posture and consider exploratory celiotomy early without ancillary radiographic localization, before organ failure progresses.

After the first postoperative week, radiographic localization by either CT or sonographic techniques can be undertaken. We rely on CT because of the usual abdominal ileus present, which impairs the sonographic image, and because CT has better resolution, in general, than sonography. If a collection is identified, either CT- or sonographic-guided percutaneous aspiration is done when feasible. Percutaneous drainage is our first line of therapy, if possible, reserving surgical drainage for patients who do not improve within 48 hours and those whose abscesses are not accessible via a percutaneous approach. Infected pelvic hematomas, which may be aspirated after radiographic localization, are too thick for adequate drainage via the PD route; therefore, after stabilization with volume resuscitation and antibiotics, open surgical drainage is instituted, preferably by using an extraperitoneal approach.

If the CT examination result is deemed normal, another source of sepsis is sought, usually pulmonary or urinary. When an extraabdominal source of sepsis has been ruled out yet the patient's clinical situation is deteriorating and the patient has had a previous celiotomy, nondirected laparotomy is considered, although the yield may be low. The nature of the original abdominal trauma such as a hollow viscus injury, the need for bowel anastomosis, a mesenteric injury, or the presence of a coagulopathy, predisposing the patient to a retained or infected hematoma, may encourage early receliotomy.

Conclusion

Sepsis is the most common cause of late death in trauma patients. Intraabdominal sepsis occurs in a significant portion of patients sustaining abdominal trauma and some without abdominal injury. Newer radiographic techniques have resulted in early diagnosis and treatment, which have helped reduce the mortality rate. Because the mortality rate of IAS with its associated organ failure is still quite high, every attempt must be made to drain all septic foci before organ failure manifests. Once organ failure is seen, rapid examination and aggressive surgical management are imperative if the critically ill trauma patient is to be saved.

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