Computed Tomography–guided Drainage of Intra-abdominal Infections

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Image-guided percutaneous abscess drainage has become a standard method of treatment of most abdominal abscesses. In most cases, it should be considered the treatment of choice, but there are selected areas and circumstances that require specific approaches and methods. Typical abscesses within solid parenchyma organs or those in the peritoneal spaces can be reliably detected and efficiently drained. Abscesses that are multiple or long and circuitous require careful placement of catheters. Management of the drainage catheters includes irrigation with fluid to minimize accumulations of material that may impair egress of fluid. In selected cases, fibrinolytic agents have proved effective in shortening the drainage times and shortening hospital stays. Some controversial areas such as splenic abscesses, pancreatic abscesses, echinococcal abscesses, and fungal abscesses should only be attempted with careful selection and meticulous technique. Successful treatment is most likely with candid consultation among the various clinical services.

Introduction

Since the first definitive computed tomography (CT)–guided drainage in 1975, the percutaneous abscess drainage (PAD) approach has become widely accepted as an important treatment tool for the patient who is critically ill because of an abscess. Experience and research over the past 28 years by Haaga *et al.* [1–3], Gerzof *et al.* [4,5], VanSonnenberg *et al.* [6,7], and Gronvall *et al.* [8] has refined techniques and clarified many aspects of the diagnosis and treatment of abscesses. However, some controversies still exist and require that interventional radiologists and consulting physicians understand the strengths and shortcomings of this valuable treatment tool as it relates relative to specific scenarios and anatomic sites [1–3,8–10,11•,12,13]. This article reviews the standard approaches to abscess drainages, discusses some new innovative methods, and gives perspectives regarding current controversies [14].

Diagnostic Methods

The modern armentarium of diagnostic imaging includes CT, ultrasound, magnetic resonance imaging, and radioisotopes, which are capable of diagnosing abscesses in many cases, although CT and ultrasound remain the mainstay for diagnosis (Fig 1). The advantages of ultrasound and CT are their almost universal availability, very high accuracy, and ability to guide diagnostic and therapeutic drainage techniques.

The diagnosis of abscess with ultrasound and CT is dependent on the visualization of fluid collections. Differentiation between sterile collections and abscesses is not definitive, but an abscess can be suggested by the overall appearance of the fluid collection and the presence of gas (Fig. 1A). Sterile fluid collections most commonly conform to the local peritoneal space and lack a spherical or elliptical shape, which suggests elevated internal pressure, characteristic of an abscess. In addition, they usually show a mass effect and displace adjacent loops of bowel or organs. Gas occurs in abscesses in several forms, as an air fluid level or small pockets of gas interspersed within the fluid. These findings are not pathognomonic in all cases because they can be produced by loculated sterile fluid collections, hematomas, fluid density tumors, fistula to bowel, or iatrogenic from local procedures.

Although ultrasound is accurate for the simple detection of an isolated fluid collection, CT is considered the modality of choice for complete evaluation of an abscess because of its unlimited imaging properties [11•]. CT is capable of accurately displaying air without impairment or artifacts, as may occur with ultrasound, and can display regional anatomy unimpaired by bone or air without loss of detail. CT can display the full extent of any fluid collection that may spread into numerous anatomic sites even remote from the most obvious fluid collection. Only visualization and knowledge of the many pathways of spread or extensions or multiple cavities can provide sufficient information to permit appropriate choice, planning, and insertion of the required catheters (number, size, type, catheter irrigant, and suction). The relationship of such fluid collections to loops of bowel, blood vessels, organs, appendix, biliary system, diverticuli, and other structures can suggest the origin of abscesses, which may or may not require surgical remedy.

The definitive diagnosis of an infection in a fluid collection or tissue is only possible by recovery of a sample

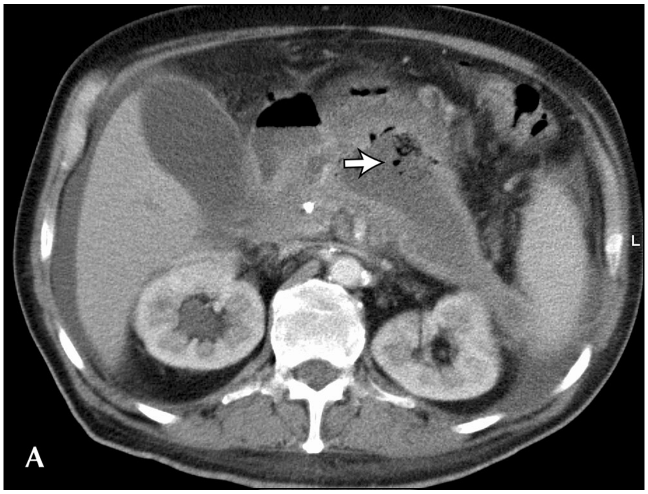

Figure 1. **A,** Patient with history of pancreatitis and attempted endoscopic drainage of pseudocyst shows persistent fluid collection with air (*arrow*) in bed of pancreas. The patient did not have fever or increased white blood cell count, but radiology consultants insisted diagnostic puncture be performed. **B,** Computed tomography (CT) scan taken during the procedure shows needle, traversing an appropriate oblique pathway through the retroperitoneum, behind the spleen (*S*), avoiding any intestine or other organs. Aspiration yields foul-smelling purulent material. **C**, CT scan after catheter insertion into the abscess cavity shows dense 14 French catheter with retaining loop.

permitting microscopic examination and culture. Just as it is not possible to diagnose infection in a urine sample by visual inspection, the examination of an anatomic fluid collection by ultrasound or CT cannot be diagnostic; a sample for examination is required. With superlative supportive methods of intensive care units and powerful antibiotics, it is uncommon for patients to succumb early to an infectious process, but even today, patients who are expectantly awaiting care may die unexpectedly. Because abscesses are a potentially fatal but curable disease, they should be given the very highest priority for treatment, and PADs are of great value. PAD can be expeditiously performed without the need for an operating suite, providing cure or palliation in most cases.

Diagnostic Aspiration

Recovery of a fluid sample can be achieved with ultrasound or CT, but several considerations are important. First, it is prudent to use a large-caliber needle rather than a "skinny needle" because purulent material may be quite thick and not recoverable except by a needle in the range of an 18 gauge. Accurate sampling without contamination of the sample is most likely achieved with CT because it can accurately depict bowel loops and peritoneal spaces without error. For superficial collections, ultrasound may suffice, but CT affords unparalleled accuracy of needle placement, increasing the safety margin (Figs. 1B and 1C).

Pyogenic Agents

Responsiveness to drainage is partially contingent on the nature of the pyogen causing the abscess. Common bacterial agents (gram-positive and gram-negative) are generally suitable for effective drainage. Antibiotic-resistant organisms are still amenable to abscess drainage according to Catalano *et al.* [15], who reported a success rate of 71% in a group of patients with abscesses caused by vancomycin-resistant enterococci. Although very little experience has been reported, one might question the prudence of attempting drainage of bacteria with aggressive lytic and enzymatic activity, such as *Streptococcus* A or *Clostridium perfringens*;

expeditious surgical debridement that permits removal of debris laden with bacteria and the open exposure to oxygen is probably more beneficial (Fig. 2).

Amebic abscesses are seldom drained because they respond well to intravenous treatment. The occasional amebic abscess that is unresponsive to standard medication may respond to PAD [16].

Fungal abscesses do not respond well because the hyphae may be very tenacious and not liquefied but also because they may grow into the surface of the cavity wall and tissues. If a fungal abscess is not chronic, direct instillation of antifungal agents through the drainage catheter in conjunction with systemic treatment may occasionally be helpful, although no study has been performed. Most are unresponsive, and surgical treatment with local debridement provides the greatest probability of resolution.

Echinococcal abscesses are parasitic collections from *Echinococcus granulosus*, which contains many daughter cysts that are capable of spillage and general dissemination if appropriate treatment/drainage is not performed. Such patients should be administered antiparasite medications such as albendazole before drainage if a bimodal percutaneous approach is performed. In such cases, the viable daughter cysts inside such an abscess must be destroyed by hypertonic saline, betadyne, or alcohol and catheter drainage. Several authors have reported on the different methods with favorable outcomes [17–20].

General Techniques

The process of percutaneous drainage can be divided into five discrete steps [11•]:

1. Diagnosis
2. Procedure planning
3. Procedure execution
4. Catheter care
5. Catheter removal

Diagnosis depends on clinical parameters and imaging findings. The most important clinical factors are temperature, white blood cell count, localizing symptoms, and pertinent history. It is rare for patients to be referred to radiology for abscess drainage without high fever and white blood cell count, but on occasion, fluid collections are found in patients without such clinical symptoms (Fig. 1). If there is any question of immunocompromise, fluid collections must be sampled. A patient who is severely immunocompromised may be unable to mount an appropriate immune response to an infectious insult, and virtually all fluid collections must be considered suspect.

The likelihood of an abscess depends on the appearance of a fluid collection. A fluid collection containing air or with curved margins as if under pressure should be sampled for culture.

Procedure planning is important to ensure the proper pathway is chosen to increase the likelihood of abscess resolution, minimize discomfort to the patient, and decrease the possibility of spread to uninvolved areas. Each circumstance must be considered individually. In general, we differ from authors [21] who minimize the risk of traversing sterile anatomic areas and think the best technique avoids or minimizes uncontaminated pathways. In each anatomic area, there usually are three or four possible approaches, but the best approach abides by this tenant. A good example of this is the area of the lesser sac or small omental bursa, located anterior the pancreas. One group has recommended using a pathway through the left lobe of the liver, but we think this is the least favorable of four possible approaches because it theoretically exposes the liver to pyogens. The most preferable choices of pathway would be through the "window" between the left lobe of the liver and the stomach or the retroperitoneum. The next preferable choice would be through the stomach itself. Studies have shown there is little adverse effect by crossing the stomach with such drainages for abscesses or pseudocysts [22]. Although inadvertent contamination in an immunocompetent patient administered potent antibiotics can be tolerated, immunocompromised or elderly patients might not fare as well.

Procedure execution is straightforward. Two general instruments/techniques are commonly used, which have changed little since our early reports on CT drainages in 1976 and 1977. The two devices are the single-step trocar device with catheter over a trocar, and the Seldinger technique using puncture needle, guidance wire, and chosen pigtail catheter. Matching the catheter size, retention loop, and the pathway of the catheter to the size and configuration of the cavity is important. This means using as large a catheter as possible but making sure the catheter is not too large and the catheter pathway matches the anatomic extent of the collection (reports show no difference in final resolution of abscess, but the time duration may be shorter [23,24]). Long, extensive abscesses traversing into different anatomic spaces will not resolve expeditiously unless the catheter extends throughout the entire pathway (see later text) [11•]. The difficulty with such large abscesses has been described by Stinner [25], who correctly notes that such extensive abscesses cannot be drained by simple insertion of a small-caliber drain. Concurrent treatment with the appropriate antibiotic also is critical because although old surgical principles did not dictate antibiotics, it is quite clear that percutaneous treatments are more effective because of the potency of modern antibiotics. Clinical expertise afforded by infectious disease experts regarding antibiotic selection, dosage, and clinical oversight are critical for the successful and timely treatment of these patients.

Catheter irrigation should be performed even though it has been underemphasized in most reports. Purulent material tends to become inspissated within the catheter

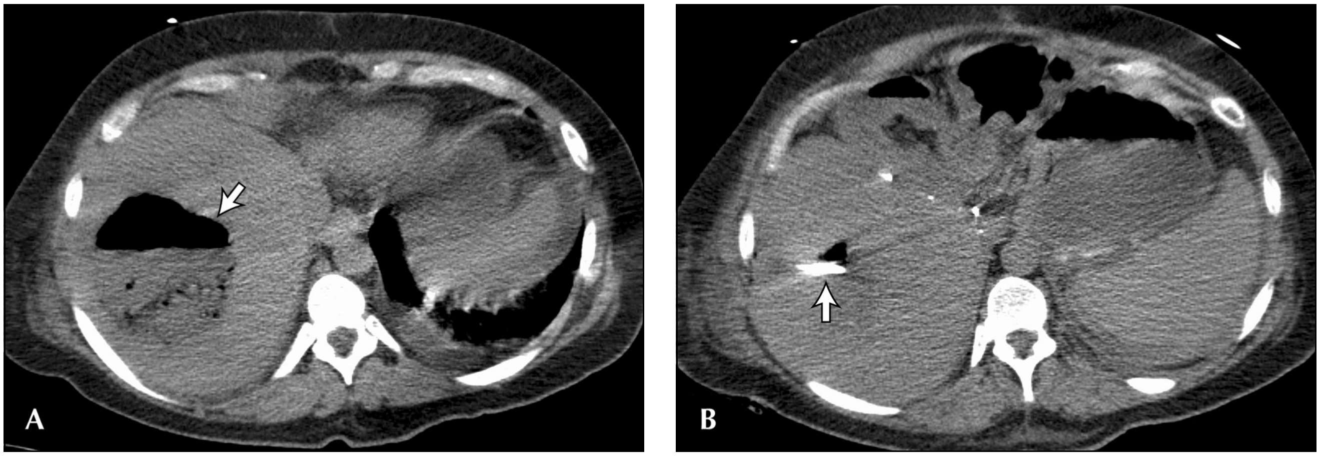

Figure 2. **A,** Large air-filled abscess (*arrow*) is noted in the liver. The most suitable pathway should include a "cuff" of normal liver and an entrance site below the level of the pleura. **B,** Scan taken during the insertion of a catheter (*arrow*) in an oblique trajectory (so entire pathway of needle cannot be seen). The entrance site is much lower than in Figure 2A, and the lower edge of the abscess cavity has been targeted, avoiding the pleural space. Also, a "cuff" of liver has been included to prevent spillage of purulent material into the peritoneal space.

lumen and effectively narrow the caliber of the catheter. This effect may delay drainage unless it is prevented by irrigating catheters with one of two agents. The two irrigants used are saline or a fibrinolytic agent such as urokinase, streptokinase, or tissue plasminogen activator. The first role of the irrigants is to minimize the inspissation of purulent material within lumen of the catheter, which may compromise the flow of material. The second purpose is to have the irrigant "thin" the material in the abscess cavity, making it more likely to completely drain.

The use of saline is very simple and straightforward. A small aliquot of saline is injected into the catheter two to three times a day because of its dilutional effect (no inherent activity). We have studied the use of fibrinolytic agents as irrigants and found them effective. The initial rationale was derived from basic animal models and chemical assays of human purulent fluid. Early reports showed that an abscess could only be created in the peritoneum in rats if bacteria were combined with a fibrin clot. Bacteria alone introduced in the peritoneum would not result in an abscess. Chemical assay of purulent material from human sources showed a very high concentration of fibrin and fibrin split products, confirming a similar role of fibrin in humans. Furthermore, Park *et al.* [23] demonstrated in vitro that fibrinolytic agents reduced the viscosity of human purulent material by almost 30%. Other authors theorized that bacteria encapsulated in fibrin could not be effectively cleared by phagocytes, and furthermore, antibiotic penetration through the fibrin was compromised. These concepts were confirmed by Nakamoto *et al.* [12], who performed two hamster animal models. Nakamoto *et al.* [13] showed that when a small foreign body of gortex was inoculated with *Staphylococcus* and implanted into a hamster, one could prove benefits of urokinase. They determined that antibiotics and urokinase resulted in significant sterility of the site, greater than antibiotics alone or no antibiotics. Furthermore, urokinase injected at the site of the innoculum resulted in approximately 20% sterility without antibiotic treatment. This additional benefit was confirmed in a second experiment that showed a foreign body of "wire" infected by *Staphylococcus* could be sterilized in 25% of the animals with only the local administration of urokinase.

Clinical reports on the use of urokinase as an irrigant were published by Lahorra *et al.* [26] and Haaga *et al.* [10]. Lahorra *et al.* [26] confirmed local urokinase irrigated into an abscess through a catheter did not produce any systemic effects. Haaga *et al.* [10] showed that in a randomized prospective study comparing saline with urokinase as an irrigant, patients receiving urokinase had a short treatment course with earlier reduction of white blood cell count, fever, and drainage output. Even if one decides to not use a fibrinolytic agent for routine abscesses, the literature is quite clear that its use may be of significant benefit for collections with thick material or septations in the abdomen or chest.

Catheter removal is the last step in the PAD process. The catheter should be removed when the following criteria have been met: the patient has improved clinically, the drainage has reduced below 10 cm^3 to 20 cm^3 per day, and a final imaging study confirms the resolution of the cavity. If there is concern about a fistula to a loop of bowel, biliary system, or renal collecting system, a sinogram should be performed. If a fistula is visualized, final resolution and prevention of recurrence are only possible if such fistulae are managed. Other contributing etiologic factors such as ulcers or Crohn's disease must be resolved if recurrence is to be avoided.

Solid Parenchymal Abscesses: Kidneys, Liver, Pancreas, and Spleen

Percutaneous abscess drainage has proven itself very effective for draining liver and renal abscesses because of their accessibility for needle aspiration, catheter placement, and ample blood supply promoting antibiotic delivery and penetration. The blood supply factor can be appreciated by noting that historically there have been numerous incidental reports observing that occasionally intravenous antibiotic therapy alone may result in resolution of renal and liver abscesses. Of course, antibiotic treatment without drainage should be considered a less optimal method of treatment that should be limited to cases in which abscesses are too small, too numerous, or the patient has an extenuating medical condition such as an uncorrectable coagulopathy.

Renal abscesses are easily treated by percutaneous drainage, and the first examples of this were by fluoroscopy and non–real-time ultrasound. The most likely reason they respond so well is that increased vascularity permits easy perfusion of antibiotics into the area because of the rich blood flow to the kidneys [27]. Drainage of renal abscesses is simple because the anatomy approach is typically straight through the retroperitoneum without intervening structures to avoid. Perinephric abscesses are easily drained, but there is one caveat if there is an associated hydronephrosis. In such cases, it is critical to drain the hydronephrosis first and then the perinephric collection. If the collecting system is not drained first, urine will leak into the perinephric space by decompression, and it may delay closure of the cavity.

Liver abscesses may be caused by a variety of factors, including associated mesenteric inflammation, biliary infection, vascular damage, and surgical or percutaneous treatments [28], and historically respond well to percutaneous drainage, assuming the blood supply is intact. Anatomic approach planning may be more intricate because the pathway used must avoid not only the pleural space, colon, and gallbladder, but also the internal vascular system of the liver if visible on the scans (Fig. 2). Puncture or drainage through medium- or large-sized vessels risks contamination and wider spread of the infection through the organ. It also has been well-demonstrated that such abscesses very commonly have internal loculations that may drain spontaneously but also may require additional treatment. The other actions that can be taken to negate these problems are insertion of more catheters or use of fibrinolytic agents such as urokinase. Extensive experience regarding hepatic abscesses has been reported by many authors, with the success rate varying between 69% and 98%, and mortality rates between 5% and 9% [29–31].

Pancreatic abscesses are very problematic because of the severe necrosis and inflammation that occurs in the gland [7,32–35]. There are two distinct types of abscesses, the infected pseudocyst and infected necrotic inflammation. The discrete pseudocyst, which is well-confined with a thick wall and secondarily contaminated by infection, responds quite well to percutaneous drainage. The infected fluid drains well through a catheter and typically resolves in as short a time as any other parenchymal abscess. Infected necrotic inflammation is much more difficult to resolve and usually requires multiple large catheters, with chronic irrigation and suction. Resolution may occur after many weeks of treatment (Fig. 1). The reported results have varied widely based on patient selection and technique at individual institutions and depend on the primary or secondary role of the PAD, with success rates between 65% and 79% [32] for drainage of fluid collections or abscesses. For drainage of infected necrosis, Mithofer *et al*. [34] and Sunday *et al*. [36] noted that when PAD was used as primary therapy, percutaneous drainage was only successful in 31% and 25% of cases, respectively. In the same study, Mithofer *et al*. [34] reported PAD success rates of 100% when used for recurrent or residual abscesses after surgery. Despite the best PAD and surgical drainage of infected pancreatic necrosis, the mortality rate is 5% to 29% [28,35,37–41]. Splenic abscess drainage is very controversial and will be discussed in a later section.

Peritoneal Abscesses: Subphrenic, Subhepatic, and Paracolic Abscesses

Pertioneal abscesses are the most common abscesses because pyogenic contamination and abscess formation in the abdomen usually occur in the peritoneum. The contamination can be the result of local perforation (*eg*, intestine, diverticulum, ulcer, appendicitis [Fig. 3]), spontaneous development, or postprocedural contamination. The approach to most of these abscesses is quite simple when the cavity borders on the peritoneal surface without other intervening anatomy.

Subphrenic spaces are a common site of abscess formation because of the normal motion of intraperitoneal fluid that "flows" from the peritoneum, cephalad to the undersurface of the diaphragms. In this manner, pyogens from lower portions of the abdomen are carried to these areas and can initiate abscesses.

The literature provides abundant information and evidence regarding the efficacy of drainages in these areas [11•,42]. With our experience over almost 30 years, we take issue with the stated incidence of complications associated with such drainages. Many authors minimize the significance of complications from soilage of the peritoneum or the pleural space, but careful study of the most extensive report provides valuable data on this technique and approach. McNicholas *et al*. [43] reported on subphrenic fluid drainages and showed the benefit of an extrapleural approach compared with a transpleural approach. In a group of 25 patients, there were 28 drainages, with eight extrapleural and 20 transpleural. Eight of the 20 transpleural approaches were intentional and 12 were unintentional. The success of the drainages was comparable, but all complications occurred in the group with transpleural drainages. The six complications in the group of 20 included inadvertent placement in the pleural space in two patients, two pneumothoraces requiring chest tubes, and two asymptomatic pneumothoraces.

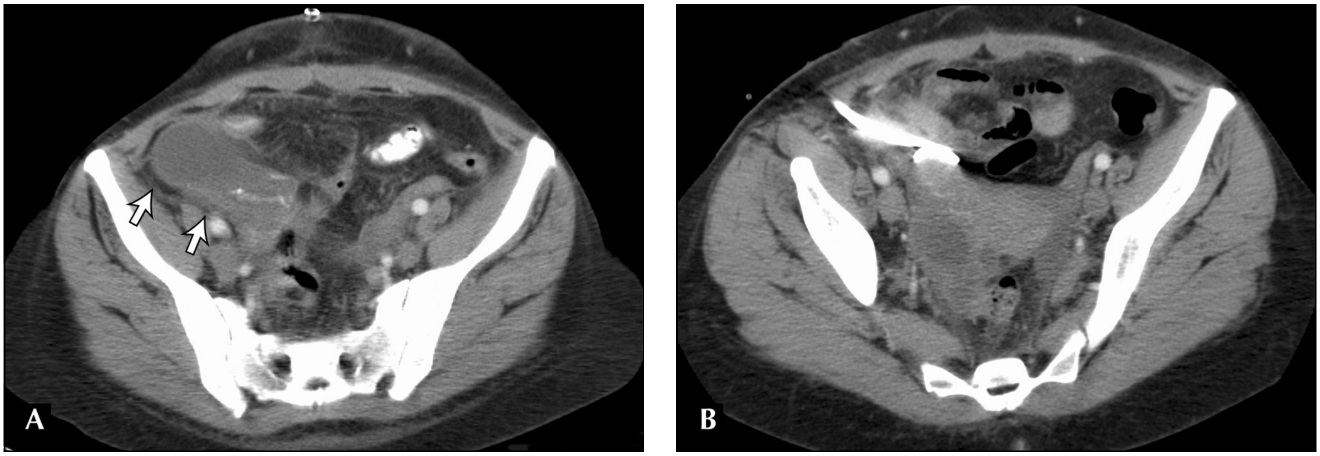

Figure 3. A, Patient with previous appendicitis shows large fluid collection in the right lower quadrant (*arrows*). **B,** Catheter was inserted through the entire length of the long pathway.

It is our opinion that these problems can be minimized by careful selection of the drainage pathway, meticulous procedure execution, and emphasis of certain details. Lessening of inadvertent catheter placement can be accomplished by appropriate patient positioning and selection of entrance site and appropriate instrument pathway. For successful uneventful drainage of subphrenic space, successful catheter placement depends on intimate knowledge of the subphrenic and pleural space. The diaphragm and the pleura are anatomically lower posteriorly than anteriorly, and thus the entrance site should not be more posterior than the midaxillary line and should be located several centimeters below the diaphragmatic insertion. Fewer complications can be assured by other techniques. Changing positions of the patient during procedures may shift the internal anatomy to enhance unimpeded anatomic drainage pathways. Having the patient lie in different angles shifts internal viscera slightly, opening "windows" (Fig. 1A). If a small amount of infected material is aspirated at the onset, potential soilage of the peritoneum can be achieved after the initial puncture of an infected collection in order to lessen the pressure of the contained material so that when the Seldinger technique is used to insert the catheter, the fluid is unlikely to leak into the peritoneum. Alternatively, one may inject carbon dioxide or saline to move intestinal loops from tentative pathways and minimize inadvertent penetration.

Retroperitoneal Abscesses

Retroperitoneal abscesses typically originate from the kidneys, perforation of colon or duodenum, spinal processes, or instrumentation. Such abscesses are amenable to drainage, but in most cases, such collections have an elongated shape, making needle puncture and placement of the catheter more critical. Effective drainage of such collections is facilitated if catheters are located throughout the length of the cavities, permitting free flow of purulent material and preventing any local loculation formation.

Success rates reported in the literature are typically lower than those for other abscesses because some authors do not strictly adhere to critical factors such as appropriate catheter placement and irrigations.

Pelvic Region

Abscesses are common in the pelvis and can be caused by several etiologies including diverticuli, appendicitis, trauma, gynecologic disorders, and postsurgery.

The anatomic approach to such abscesses is quite varied and can be through the abdominal wall, sciatic notch [44,45], or transvaginal [46] or transrectal [47–50] pathways. Selection of the pathway depends on the location, but the abdominal wall approach is generally preferable, followed by a transvaginal or rectal approach. Although the trans-sciatic notch approach has been used widely, it is somewhat more painful and subject to catheter displacement/kinking because of the proximity of the boney pelvis and the large gluteal muscles. It has been our preference to drain very low abscesses in the pelvis by a transrectal approach, which is well-tolerated in all patients, including children. In more than 30 cases, we have not had a failure or complication from such transrectal approach.

Complications

Complications vary according to the anatomic site that is drained, the technique used, and the underlying etiology of the abscess. Complications include death, sepsis, misplaced tubes, bowel perforation, hemorrhage, generalized peritonitis, and contamination of the pleural space. Overall, the lowest complication rate is 1.4% with hepatic abscess drainage, whereas the highest rate is 30% and associated with splenic drainages.

Sepsis, which occurs in 4.6% to 5% of cases, can be minimized by two actions. All patients should be administered broad-spectrum antibiotics at the time of the procedure or immediately after the puncture. In addition, during placement of the catheter, the interventionalist should minimize excessive manipulation of the catheter, which may introduce hematogenous bacterial spread. Other problems can be lessened by careful procedure planning and meticulous execution of the procedure. Soilage of an adjacent sterile anatomic space is infrequent but most likely occurs in the subdiaphragmatic area, where access to most abscesses requires an angled approach to avoid solid organs and the pleural space. When contamination of the pleural space or peritoneal space occurs, the effects can be remedied if additional drainage catheters are inserted into the secondarily involved site. Spillage from peritoneal loculations into the general peritoneum can be avoided if, during the initial puncture of the cavity, a sufficient volume is removed to decrease the local pressure and leakage during the insertion or exchange of catheters. Authors agree that CT guidance is the gold standard for guiding such procedures, and inadvertent puncture of bowel loops or other organs can be easily imaged and avoided.

Controversial Topics

Diverticular abscesses

Diverticular abscesses are an excellent example of how collaboration between infectious disease specialists, surgeons, and interventional radiologists can provide great benefit for patient care (Fig. 4). Patients with long-standing diverticular disease may be managed medically for many years until they present with sepsis and a localized abscess. Once an abscess occurs and does not drain spontaneously into the bowel, most of these patients require surgical treatment to prevent abscess recurrence. Within this context, PAD can temporize the immediate need for surgery and simplify the treatment by eliminating the need for two-step surgical treatment [25]. When such abscesses are large, prior surgical approach would require surgical diversion and abscess drainage, to be followed later by a reanastomosis. With collaborative therapy, PAD can effectively drain the abscess and clinically stabilize the patient so that the surgical resection and reanastomosis can occur with a single surgical procedure. When communication is clear among specialists, there is little controversy. Differences in opinion occasionally develop based on two premises. Some are unwilling to follow such abscesses when internal, spontaneous drainage is likely; such cases do not require immediate radiologic or surgical intervention. The second clinical scenario that causes some intense discussion is patients with small abscesses that are suitable for removal with a primary resection and anastomosis with a single surgical procedure.

Patients with Crohn's disease

Abscesses in patients with Crohn's disease are amenable to percutaneous drainage but may be problematic because of ongoing inflammatory disease and fistulae. Final resolution depends on general management and local control of the fistula. Low-output fistulae resolve spontaneously, but high-output fistulae require high suction on catheters in the proximity of the fistula. Lambiase *et al.* [27] drained nine patients with 11 enteric communications and determined that only one patient was cured by PAD alone, but seven were temporized. The only patient cured had a very low-output fistula to the sigmoid colon. Garcia *et al.* [51] reported on the recurrence rate of abscesses in patients with Crohn's disease treated with surgery and those with medical/percutaneous management. The recurrence rate was only 12% for the surgical group and 56% by the conservative method. Casola *et al.* [52] reported on 15 patients with Crohn's disease and abscesses, all of whom were successfully drained. No surgery was required. Excluding fistulae in four of seven patients, no fistulae developed as a result of the drainage.

As evidenced by these experiences, success with patients with Crohn's disease is quite variable and depends on the individual patient and patient referral patterns. The variable factors include severity and extent of the disease, immune status, treatment regimen, and number of prior attacks and surgical treatments.

Splenic abscesses

Splenic abscesses are unusual processes and difficult to manage because most are associated with serious clinical problems such as immunocompromise, transplantation, AIDS, or thromboembolic events. The most common causative organisms worldwide are *Staphylococcus*, *Salmonella*, and *Escherichia coli*. The standard surgical treatment is resection of the spleen, but there is a great emphasis on preservation of splenic function. Accordingly, several authors have reported the PAD treatment approach preserves the immune system and splenic integrity. Although such procedures are technically quite straightforward, the spleen is very vascular and subject to hemorrhage. This is the one organ in which the anatomic approach varies from that used with other solid organs. Unlike the liver and kidney, the spleen is so vascular that we think one should avoid the splenic pulp because the risk for hemorrhage is greater than the risk for spillage of purulent material. Green [9] and Lucey *et al.* [53] have reported and reviewed splenic procedures and advocate them in selected instances in which the potential benefit of splenic salvage exceeds the risk for emergent splenectomy. The success rate among authors varies between 25% and 65%, and the complication rate varies between 10% and 30%, with patients requiring emergent splenectomy because of hemodynamic instability [9,53].

Even with our 30 years of experience and confidence with any type of percutaneous procedure, we have little enthusiasm for splenic procedures except in the most unusual circumstances because of the potential high complication risk.

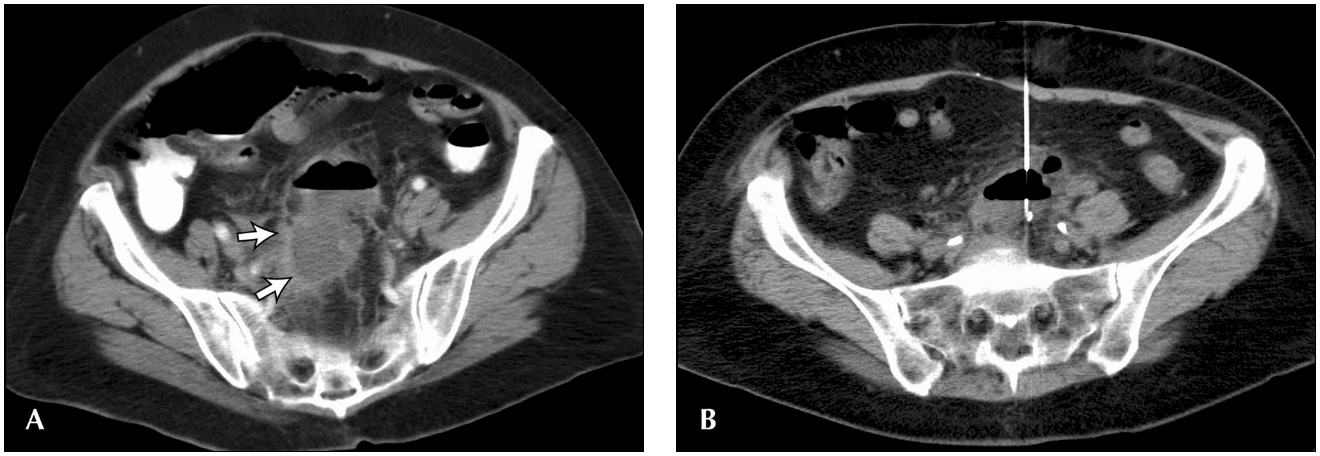

Figure 4. A, Patient with history of diverticulitis shows large fluid collection with air fluid level in mid-abdomen (*arrows*). This fluid collection was in immediate proximity to diverticula of the sigmoid colon. **B,** Scan during procedure shows path of needle with inserted wire, extending into the abscess cavity. The abscess subsequently resolved, permitting a later single-step resection of the site and reanastomosis of the bowel.

Nondrainage treatment of abscesses

The treatment of small abscesses without drainage is a controversial topic but a useful method in appropriate cases [54–57], and there are two approaches reported. There are a limited number of reports that describe successful treatment of abscesses by intravenous antibiotics alone, but this is not considered by most experts as optimal treatment. The second approach has been needle aspiration of small abscesses combined with subsequent local intracavitary injection of antibiotics. When abscesses are too small for drainage or too numerous for effective catheter placement, percutaneous puncture, aspiration, and injection of antibiotics may prove effective. This technique is very simple and straightforward. After purulent material is aspirated, a single dose of appropriate antibiotic is injected. The dose should approximate a single intravenous dose, and the volume of the injected medication should not exceed the fluid removed. The choice of a broad-spectrum antibiotic should be made before the procedure, with consultation of all clinical services.

Success Rates

Success rates vary according to the anatomic areas being treated and other parameters related to the pyogens and the clinical status of the patient. The overall rate varies between 62% and 90% among the many groups because of technique differences, different types of abscesses, and patient mixture at the different institutions. General clinical status of the patient also has a large impact on successful outcome. Lambiase *et al.* [27] assessed the effect of the immune system and severity of illness graded by the Acute Physiology and Chronic Health Evaluation II system. Lambiase *et al.* [27] determined that immunocompetent patients had a successful outcome in 72.6% of cases, compared with a 53.4% success rate for immunocompromised patients. Surprisingly, Civardi *et al.* [58] reported that patients with leukemia and lymphoma responded well to percutaneous abscess aspirations and drainage, with a success rate of 86%.

Conclusions

Percutaneous drainage of abdominal abscesses is an important technique that has now become standard therapy for most clinical situations. With proper management and consultation among the radiologists, surgeon, and infectious disease physicians, outcomes are remarkably favorable in most circumstances, with few complications. There are unique types of abscesses that are less amenable to PAD and more suitable for surgical intervention, such as abscesses of fungal origin or abscesses of the pancreas and spleen.

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- • Of importance
- •• Of major importance

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