Percutaneous Drainage of Abdominal and Pelvic Abscesses in Children

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Semin Intervent Radiol 2012;29:286–294

Abstract

Keywords

- interventional radiology
- pediatric
- abscess drain
- appendicitis
- percutaneous therapy

It has only been in the last several decades that abscesses within deep compartments, particularly within the abdomen and pelvis, have become safely accessible with imaging guidance. Since that time, percutaneous abscess drainage has become the standard of care in children. We review the clinical features, diagnosis, and image-guided management of abdominal and pelvic abscesses in children.

Objectives: Upon completion of this article, the reader will be able to discuss the role of percutaneous catheter drainage of abdominal and pelvic abscesses in children, as well as the unique challenges facing the interventional radiologist in this patient population.

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In 1842, a surgeon named Murray described a method of liver abscesses drainage by “introduction of an ordinary-sized trocar and canula, leaving the latter in position until adhesions formed between the liver and abdominal wall.”¹ However, open surgical drainage remained the primary treatment for abdominal and pelvic abscesses over the next century. It has only been in the last few decades that abscesses within deeper structures, particularly within the abdomen and pelvis, became safely accessible with image guidance. Since that time, percutaneous abscess drainage (PAD) has become the standard of care in children.^{2,3} In this article, we review the clinical features, diagnosis, and image-guided management of abdominal and pelvic abscesses in children.

Appendix

Acute appendicitis with perforation is the most common cause of abdominal or pelvic abscess in children.⁴ Perforation complicates pediatric appendicitis in 23 to 73% of cases.^{4,5} Perforation is more common in younger children, occurring in up to 66% in children <5 years of age and in almost 100% of infants.⁶ When all children with appendicitis are considered, perforation with abscess formation is present in 10 to 13%.^{4,5} Although most periappendiceal abscesses are located in the pelvis, they may occur anywhere in the peritoneal cavity and retroperitoneum.^{4,7}

Although acute appendicitis may be diagnosed clinically in patients with a classic presentation, imaging is a useful adjunct when the diagnosis is equivocal. Sonography and computed tomography (CT) are the primary imaging modalities used to diagnose appendicitis in children.⁸ A staged approach, using CT when sonography is nondiagnostic, achieves a high level of diagnostic accuracy while reducing radiation exposure in accordance with the principles of ALARA (as low as reasonably achievable).⁹ However, when periappendiceal abscess is suspected, CT is the preferred modality.⁸

Patients with uncomplicated appendicitis benefit from immediate appendectomy. When periappendiceal abscess is present, early surgery is associated with an increased risk of hemorrhage, wound infection, and fistula or adhesion formation. In stable children with perforated appendicitis

Issue Theme Biopsies and Drains; Guest Editor, Jonathan M. Lorenz, MD, FSIR

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Tel: +1(212) 584-4662.

DOI <http://dx.doi.org/10.1055/s-0032-1330062>.
ISSN 0739-9529.

Figure 1 Appendiceal abscess. A 14-year-old boy with perforated appendicitis was referred for computed tomography (CT). (A) Diagnostic axial contrast-enhanced CT revealed a deep pelvic abscess (arrow). (B) An 8F catheter (arrow) was placed via a transgluteal approach using the Seldinger technique.

complicated by abscess, intravenous antibiotics and image-guided catheter drainage (►Figs. 1 and 2) are the principal means of initial management. Elective appendectomy is performed at a later date.⁶ However, early surgery is recommended in children <5 years of age, those who present with shock or systemic toxicity, and in children with severe comorbidities.⁵

Technical and clinical success rates for PAD range from 85 to 90% and 81 to 100%, respectively.^{4,6,7,10} The complication rate of nonoperative management, reported as 0 to 15%, compares favorably with reported complication rates of 26 to 58% for early operation.^{5,11} Additionally, length of hospital stay and costs are lower in those patients treated with PAD and elective appendectomy than those who undergo early surgery.⁵

Crohn Disease

Bowel inflammation in Crohn disease (CD) is often complicated by abscess formation, with a lifetime incidence of abscess formation in 10 to 30%.^{12,13} These abdominal or pelvic abscesses may form via direct extension from ulcerated bowel or as a result of peritoneal contamination during surgery.^{14,15}

CT is the current test of choice for evaluating CD patients with suspected abscesses in the abdomen and pelvis. However, advances in magnetic resonance imaging (MRI) have created a viable alternative means of imaging Crohn complications while sparing patients the high cumulative radiation doses associated with frequent CT scans. Sonography may also have a role in the evaluation of abdominal and pelvic complications of CD in children.¹⁶

PAD in CD is usually accomplished by catheter drainage (►Fig. 3). Aspiration without drain placement is prone to failure because the abscess cavities frequently communicate with bowel via fistulae.¹² In CD patients with multiple abscesses, the dominant collections are treated with catheter drainage, whereas small collections (1 to 2 cm in diameter) generally resolve with antibiotic treatment alone. Surgical therapy may be preferable in patients with three or more large collections.¹²

PAD of Crohn abscesses has reported technical success rates ranging from 53 to 100%. Clinical success of PAD in CD abscesses is limited, especially when longer follow-up periods are considered. In a study of pediatric and adult patients, the short-term (<60 days) success rate was 50%; 23% avoided surgery on a long-term basis.¹³ Although PAD may lead to

Figure 2 Appendiceal abscess. A 7-year-old boy with perforated appendicitis was referred for computed tomography (CT). (A) Diagnostic axial contrast-enhanced CT revealed a deep pelvic abscess (arrow). (B) As the initial step of the Seldinger technique, a needle was advanced under transabdominal sonographic guidance into the abscess (arrow) via a transrectal approach. (C) Postprocedure fluoroscopy showed proper positioning of an 8F catheter.

Figure 3 Crohn abscess. A 15-year-old girl with Crohn disease and fever was evaluated with magnetic resonance imaging. (A) Contrast-enhanced fat-saturated T1 image showed a right lower quadrant abscess (arrow). (B) Using an anterior transperitoneal approach, a needle (arrow) was introduced into the abscess under sonographic guidance. (C) Under fluoroscopy, contrast injection into the abscess cavity (arrowhead) revealed a fistulous connection to the right colon (arrow). (D) Fluoroscopy showed proper positioning of the 8F catheter within the abscess cavity.

resolution of abscesses in CD patients, it does not address the underlying diseased bowel, and many patients ultimately undergo surgery.^{13,14} Nonetheless, PAD is important as a temporizing measure, avoiding the morbidity associated with early surgery.^{13,14,17} Additionally, complicating fistulae are less common with PAD than with surgical drainage.¹³

Liver

Hepatic abscesses in children can be grouped into three major categories: pyogenic liver abscesses (PLAs) in nonneonates, neonatal pyogenic liver abscesses (NLAs), and amebic liver abscesses (ALAs). PLAs are associated with a variety of causes and risk factors, including portal sepsis from gastrointestinal sources, chronic granulomatous disease (CGD), leukemia, and diabetes mellitus.^{18–20} NLAs most commonly occur in premature infants; underlying causes include umbilical venous catheter infection or malpositioning, necrotizing enterocolitis, and hematogenously disseminated infection.^{19,21} ALA is the most common extraintestinal manifestation of *Entamoeba histolytica* infection and can occur in developed countries due to immigration or travel.²²

Most abscesses occur in the right hepatic lobe. Regardless of etiology, hepatic abscesses may be single or multiple.¹⁸ Both sonography and CT are highly sensitive in the detection of liver abscess.²³ Hepatic abscesses appear on sonography as simple or complex hypoechoic collections within the liver parenchyma; on CT, hepatic abscesses are low attenuation

collections with rim enhancement that may have septations, loculations, or intralesional gas.^{24,25}

PAD is the definitive treatment of choice for most hepatic abscesses and may be performed by needle aspiration or catheter drainage (→ **Fig. 4**). Multiple abscesses, large abscesses, and loculated abscesses can be successfully managed with PAD.^{23,26} Most outcome data available regarding PAD of PLAs are derived from series of primarily adult patients. Clinical success rates range from 60 to 100%^{26–28} with complication rates reported from 0 to 31%.^{26,28} A randomized trial of 64 adults with PLA treated by needle aspiration or catheter drainage found the two methods essentially equivalent in terms of safety and efficacy.²⁹

Surgical drainage of PLA is reserved for selected patients in whom PAD cannot be accomplished or who fail to respond to antibiotics and percutaneous drainage.^{23,26} Surgical drainage may also be preferable in patients with CGD due to the presence of numerous fibrous septations within the abscess cavity.²⁰ Antibiotic therapy alone can be used in patients who have abscesses that are too small and numerous for drainage.³⁰

Data regarding management of NLA are limited. Antibiotic therapy is important and may be adequate in some cases; however, percutaneous needle aspiration and catheter drainage have been successfully used in this scenario. Two small series report success rates of PAD of 100% and 66%, with no major procedure-related complications.^{19,21}

In contrast to PLAs, medical therapy, most commonly metronidazole, is curative in most patients with ALA. PAD is generally unnecessary in this patient population.^{31–33}

Figure 4 Liver abscess. A 14-month-old boy with spontaneous liver abscess. (A) Diagnostic axial contrast-enhanced computed tomography revealed abscess in the right hepatic lobe (arrow). (B) The abscess was accessed with a needle (arrow) using a transhepatic approach and sonographic guidance. (C) Postprocedure fluoroscopy confirmed appropriate positioning of a 14F catheter.

However, PAD can be used when the response to medical therapy is inadequate.³¹ Drainage should also be considered for left hepatic lobe abscesses at risk of rupture into the pericardial space because this complication can be fatal.³²

Kidney

Renal and perirenal abscesses are uncommon in children. Renal abscesses (RAs) result primarily from hematogenous infection and ascending genitourinary infection. Perirenal abscesses (PrAs) are generally due to capsular penetration of a renal abscess, infection extending from adjacent organs, or surgical contamination.^{34–36} PrAs may extend into the pararenal space, involving the psoas muscle, and into the pelvis and groin.³⁶

Sonography is the initial imaging study of choice for detecting RAs and PrAs in children.³⁷ The typical appearance is a well-defined hypoechoic fluid collection. However, distinguishing between RA and focal bacterial pyelonephritis (FBP), which is treated by antibiotic therapy alone, can be challenging when a poorly marginated hypoechoic lesion is visualized.^{36,38} CT is the most sensitive and specific imaging modality in diagnosing RAs and PrAs, and it may be used

when sonography is equivocal.^{36,37} The CT appearance of a RA is a well-defined low attenuation lesion with an enhancing pseudocapsule in a nonlobar distribution.^{36,38} In contrast, FBP is poorly defined and in a lobar distribution.³⁸ However, FBP progresses to abscess in 25% of cases.³⁴

The risk of kidney loss in pediatric patients with RA is 16 to 25%.³⁴ Prompt drainage (►**Fig. 5**) minimizes loss of kidney function.^{34,39} Surgery is needed only when there is diffuse kidney damage and uncontrolled infection.^{35,40} Smaller renal abscesses may respond to antibiotic therapy alone.⁴¹

Although outcome data in pediatric patients are sparse, PAD is considered safe and effective for treatment of RAs and PrAs in children. Adult studies report an overall cure rate of 73 to 92%,³⁴ with efficacy equivalent to that of open surgical drainage.⁴² Perirenal abscesses resulting from gastrointestinal infection may have associated fistulae and require prolonged drainage.³⁴

Pancreas

Acute pancreatitis is uncommon in children. Nearly 80 etiologies have been reported; abdominal trauma and structural anomalies are among the leading causes.⁴³ Infection is a

Figure 5 Renal/perirenal abscess. An 11-year-old girl with fever and flank pain. (A) Diagnostic axial contrast-enhanced computed tomography (CT) demonstrated a complex right renal/perirenal abscess (arrows). The patient was treated with needle aspiration (not shown) and antibiotics. (B) Follow-up CT obtained 1 year after the procedure showed resolution of the abscess with residual parenchymal scarring.

potential complication of acute necrotizing pancreatitis. Three major forms of infection have been identified: infected necrosis, walled-off pancreatic necrosis (WOPN; previously known as pancreatic abscess), and infected pancreatic pseudocyst. Infected necrosis (IN) is defined as intrapancreatic or extrapancreatic necrotic tissue with microbiological evidence of infection but without a dominant pus collection. WOPN, in contrast, is a pus-filled cavity in or near the pancreas.⁴⁴ Pancreatic pseudocysts are loculated fluid collections that occur secondary to acute pancreatitis. In children, pseudocysts may occur anywhere from the diaphragm to the pelvis.⁴⁵ Pseudocysts can become infected, particularly those that are large (>6 cm) or persistent (present for >6 weeks).⁴⁶ Infection is attributed to translocation of bacteria from the gut flora.⁴⁷

The presence and extent of pancreatic necrosis correlates with morbidity and mortality and predicts the probability of subsequent infection.^{48,49} Infected fluid collections complicating acute pancreatitis can be multiple and may occur throughout the peritoneal cavity or retroperitoneum. Therefore, CT is the preferred imaging modality, although MRI may serve as an alternative.^{47–50} Sonography is subject to significant limitations including incomplete visualization of the pancreas and retroperitoneum. Additionally, in patients with acute pancreatitis, paralytic ileus can lead to severe and persistent obscuration of abdominal and pelvic structures by bowel gas.⁵¹

Although limited outcome data are available for pediatric patients, several authors have described successful percutaneous management of pancreatitis complications in children.^{52–54} Patients with IN have historically been treated with surgical debridement.⁵⁵ However, successful nonsurgical management of IN with percutaneous drainage, endoscopic drainage, and/or endoscopic necrosectomy has been described in adults.^{55,56} In adults, the clinical success rate of PAD for WOPN varies widely, ranging from 32 to 90%. These erratic results are likely in part attributable to inconsistent categorization of infectious complications of acute pancreatitis.²¹ The reported clinical success rate of percutaneous

catheter drainage of infected pseudocysts (→**Fig. 6**) has been reported as 94% in a mixed pediatric and adult population.⁵⁴

Spleen

Splenic abscesses (SAs) are rare.^{57,58} Mechanisms of SA formation include hematogenous spread of infection, superinfection of splenic tissue injured by infarction or trauma, and contiguous spread from adjacent organs. Immunosuppression is an important risk factor.^{59,60}

CT is reported to be the most sensitive diagnostic test for detecting SAs.^{59,61} Although sonography is less sensitive than CT, the absence of ionizing radiation makes it a useful tool in pediatric patients with suspected SA.^{59,60} There is little information regarding the use of MRI for the diagnosis of SA, but it is likely to have accuracy comparable with that of CT.⁵⁹ SAs appear as hypoechoic fluid collections on sonography and low attenuation lesions with rim enhancement on CT. The presence of multiple SAs is suggestive of fungal or mycobacterial infection.^{60,61}

Much of the published information regarding PAD of SAs in children consists of case reports, small case series, and adult case series that include occasional pediatric patients.^{57,58,60–62} In the past, percutaneous splenic interventions were largely avoided because of the perceived risk of hemorrhage and the spleen's proximity to the colon and diaphragm.^{57,62} However, many authors have since published reports of successful percutaneous SA aspiration and catheter drainage in children and adults with low complication rates.^{57,59,62}

Medical therapy alone may be adequate for treatment of fungal SAs, mycobacterial SAs, and some small bacterial abscesses.^{60,61,63} However, surgical or image-guided drainage (→**Fig. 7**) is required for definitive management of most bacterial SAs.⁵⁹ Splenectomy is the traditional standard for management of SA.^{60,64,65} However, splenectomy carries a risk of operative morbidity and mortality and puts the patient in danger of postsplenectomy sepsis.⁶⁵ Postsplenectomy

Figure 6 Infected pancreatic pseudocyst. A 5-year-old boy with persistent fever following drainage of a pancreatic pseudocyst. (A) Diagnostic axial contrast-enhanced computed tomography (CT) revealed a drainage catheter (white arrow) in the left upper quadrant as well as a gas-containing fluid collection in the retroperitoneum (open arrow). (B) Contrast injection into the existing 10F catheter demonstrated communication between the collections. (C) Follow-up CT after catheter repositioning showed resolution of the infected pseudocyst.

Figure 7 Splenic abscess. A 13-year-old girl with left upper quadrant abdominal mass. (A) Sonography showed a complex cystic collection within the spleen (arrow). Aspiration yielded purulent material, and an 8F catheter was placed. (B) Postprocedural computed tomography demonstrated evacuation of the abscess cavity.

sepsis is reported to occur in 3.3% of children who undergo splenectomy and is fatal in approximately half of these patients.⁶⁶ With modern imaging technology, PAD of SAs can be performed with a high success rate and relative safety. As a result, PAD is the treatment of choice for SA.^{65,67} Some authors recommend needle aspiration for abscesses <4 to 5 cm^{57,68} and catheter drainage for larger or recurrent abscesses. Additionally, several sources recommend that the drainage device be inserted using a route that traverses the smallest possible amount of normal splenic tissue; this recommendation is hypothesized to reduce the risk of hemorrhage.^{62,65,68}

Image-guided SA drainage has a success rate of 51 to 100%.^{62,65} SAs that consist of a single cavity with a well-defined wall are most likely to resolve with PAD.⁶⁵ Relative contraindications to PAD include multiple abscesses, the presence of more than one internal septation, coagulopathy, and hilar location.^{59,62,65,67} Procedural complications are uncommon but include splenic hemorrhage and pneumothorax or pleural effusion if a needle or catheter traverses the pleural space.^{62,65,67}

Adrenal

Pediatric adrenal abscesses are rare with scattered cases reported predominantly in neonates. The etiology is hypothesized to be secondary infection of adrenal hemorrhage.⁶⁹ Arriving at the diagnosis of an adrenal mass can be complicated. Abscess is a consideration when a cystic adrenal mass is detected; however, even with advanced imaging and laboratory evaluation, distinction from other cystic lesions such as evolving hematoma and cystic neuroblastoma is difficult.^{69,70}

Sonography is generally used for initial evaluation because the adrenal glands are readily visible in young infants.⁷¹ The typical sonographic appearance of an adrenal abscess is a complex cystic suprarenal lesion with a thick wall that inferiorly displaces the kidney.⁶⁹ The CT appearance is similar with characteristic rim enhancement when intravenous contrast is administered.⁶⁹ On MRI, adrenal abscesses may display variable T1 signal due to hemorrhage and proteina-

ceous material.⁷¹ Antigranulocyte antibody scintigraphy may be useful for diagnosing adrenal abscess.⁷⁰

Traditionally, adrenal abscesses have been managed surgically. However, several reports describe successful image-guided percutaneous aspiration and drainage of pediatric adrenal abscesses.⁷⁰

Preprocedural Management and Sedation

The decision to perform PAD should be made with multidisciplinary input after consideration of the possible treatment approaches. In pediatric patients, informed consent should be obtained from the child's parent or legal guardian after a discussion of the procedure along with its benefits, risks, and alternatives. Preprocedural coagulation studies are not mandatory but may be obtained in patients with a history of bleeding diathesis or clinical suspicion of elevated bleeding risk.^{4,72}

Most PAD procedures in pediatric patients require sedation or general anesthesia. Sedation should be provided by qualified personnel who are prepared to safely administer the required medications, perform monitoring during the procedure and recovery, and manage potential complications.^{73,74} Local anesthesia is valuable in decreasing patient discomfort and potentially decreasing the required depth of sedation. Judicious administration of local anesthetic at sites that produce the most pain with needle transgression (e.g., peritoneum, organ capsules) can maximize these benefits.⁷⁵ Dosage guidelines based on the patient's body mass should be observed to prevent systemic toxicity from local anesthetic agents.

Image Guidance and Technical Considerations

Sonography, CT, and fluoroscopy are the imaging modalities most frequently used for PAD. The choice of image guidance is individualized for each case based on abscess location, patient factors, operator experience and preference, and equipment availability.⁷⁶

Sonography is preferred in pediatric patients due to the absence of ionizing radiation and is often practical due to the smaller size of pediatric patients.^{76–78} Fluoroscopy is often used as a supplement in sonographically guided procedures, aiding and confirming proper guidewire and catheter placement, and in some cases to detect fistulous communications.^{7,79,80} Fluoroscopic dose can be decreased by using pulsed fluoroscopy with the photograph-and-store (“last image hold”) option, collimating appropriately, and using the lowest required level of magnification, decreasing the distance between the patient and image intensifier, and shielding radiosensitive organs.⁴¹

PAD may be performed using the Seldinger technique or the trocar technique.^{76,81} The Seldinger technique is a multistep procedure in which dilation and drain placement are performed after proper needle placement is confirmed. When the Seldinger technique is used, initial access can be obtained in many cases with a 21-gauge needle through which a 0.018-inch guidewire is introduced. When greater purchase is required or when an organ with fibrous parenchyma is punctured, a larger diameter system (18-gauge needle and 0.038-inch guidewire) may be used.^{75,82} The trocar technique, which is a one- or two-step procedure, may be performed with or without a tandem guiding needle. This technique may be preferable when crossing resistant structures (such as the gluteal muscles) or when serial dilation steps of the Seldinger technique would increase patient discomfort.^{80,82} In addition, the trocar method avoids the possibility of losing guidewire access during dilator exchanges performed when using the Seldinger technique.⁷⁶ Catheter sizes used for PAD in children usually range from 5 to 12F, depending on patient size and the viscosity of the abscess contents.^{6,12,21,78}

The approach may be chosen based on abscess location and operator experience and preference.^{52,80,83} PAD catheters should generally be placed using an approach that avoids transgressing adjacent critical structures, facilitates gravity drainage, and minimizes patient discomfort.^{84–86} However, some procedures may require catheter placement via approaches that transgress adjacent organs. For example, lesser sac collections complicating acute pancreatitis can be safely approached by transgastric and transhepatic routes.^{46,52,83,87}

Acute appendicitis is the most common cause of deep pelvic abscesses in children.^{80,85,88} Pelvic abscesses in children can be drained via a variety of specific routes including transgluteal and transrectal approaches. The transperineal, transurethral, and transvaginal methods described in adults are not used in children. Although some authors have reported poor tolerance of transgluteal drains due to pain, recent series describe good results in children.^{84,85} Placing the catheter caudal to the piriformis muscle avoids nerves of the sacral plexus and decreases patient discomfort.⁸⁹ Transgluteal catheters are usually placed with CT guidance (►Fig. 2).^{84,85,89} Although uncommonly used, transrectal drains can be placed using transrectal sonography or transabdominal sonography (►Fig. 1) with the full bladder as an acoustic window.^{88,90}

When PAD fails to drain an abscess adequately due to septations or highly viscous contents, thrombolytic agents

may be used to facilitate complete evacuation of abscess contents.^{7,81,91} In adults, intracavitary urokinase decreases length of hospital stay and treatment costs in patients who undergo PAD.⁹¹ Additional studies that included pediatric patients have shown that intracavitary tissue-type plasminogen activator is an effective adjunctive treatment for complicated abscesses. No bleeding complications were observed in these studies.^{7,81}

Postprocedural Management

Patients who undergo PAD should be seen daily by the member of an interventional radiology team until catheter removal. Daily rounding aids in early identification of catheter complications and improves multidisciplinary coordination.⁹² Patients should be monitored for recurrent fever, and the drainage volume should decrease with clinical improvement.^{4,75} Routine catheter care includes 5- to 10-mL flushes every 8 to 12 hours to prevent occlusion of the drain by debris.^{4,41,82} The volume of the flushes should be subtracted from the overall drainage amount.⁴

Catheter removal may be considered when the patient is clinically improved and no longer febrile, and catheter output has decreased to <5 to 10 mL/day.^{27,72,86} Patients with an uncomplicated clinical course and decreasing catheter output generally need no follow-up imaging. However, a persistent fever, lack of clinical improvement, or continued drain output should prompt repeat imaging.⁴¹ Prolonged drainage may be expected in abscesses associated with CD and infected pancreatic pseudocysts because they are often associated with fistulae.^{12,51}

Conclusion

PAD is effective and associated with a low rate of complications. Due to its ability to spare patients the morbidity associated with traditional surgical therapy, PAD is now a first-line management for abdominal and pelvic abscesses in children.

References

- 1 Briddon CK III. Surgical observations in the treatment of the diseases and accidents of the Liver. *Ann Surg* 1885;2(7):51–61
- 2 Towbin RB. Pediatric interventional procedures in the 1980s: a period of development, growth, and acceptance. *Radiology* 1989;170(3 Pt 2):1081–1090
- 3 Mueller PR. The evolution of image-guided percutaneous abscess drainage: a short history. *Semin Intervent Radiol* 2003;20(3):171–176
- 4 Hogan MJ. Appendiceal abscess drainage. *Tech Vasc Interv Radiol* 2003;6(4):205–214
- 5 Whyte C, Levin T, Harris BH. Early decisions in perforated appendicitis in children: lessons from a study of nonoperative management. *J Pediatr Surg* 2008;43(8):1459–1463
- 6 McNeeley MF, Vo NJ, Prabhu SJ, Vergnani J, Shaw DW. Percutaneous drainage of intra-abdominal abscess in children with perforated appendicitis. *Pediatr Radiol* 2012;42(7):805–812
- 7 McCann JW, Maroo S, Wales P, et al. Image-guided drainage of multiple intraabdominal abscesses in children with perforated appendicitis: an alternative to laparotomy. *Pediatr Radiol* 2008;38(6):661–668

- 8 Rosen MP, Ding A, Blake MA, et al. ACR Appropriateness Criteria® right lower quadrant pain—suspected appendicitis. *J Am Coll Radiol* 2011;8(11):749–755
- 9 Krishnamoorthi R, Ramarajan N, Wang NE, et al. Effectiveness of a staged US and CT protocol for the diagnosis of pediatric appendicitis: reducing radiation exposure in the age of ALARA. *Radiology* 2011;259(1):231–239
- 10 Jamieson DH, Chait PG, Filler R. Interventional drainage of appendiceal abscesses in children. *AJR Am J Roentgenol* 1997;169(6):1619–1622
- 11 Levin T, Whyte C, Borzykowski R, Han B, Blitman N, Harris B. Nonoperative management of perforated appendicitis in children: can CT predict outcome? *Pediatr Radiol* 2007;37(3):251–255
- 12 Rypens F, Dubois J, Garel L, Deslandres C, Saint-Vil D. Percutaneous drainage of abdominal abscesses in pediatric Crohn's disease. *AJR Am J Roentgenol* 2007;188(2):579–585
- 13 Gervais DA, Hahn PF, O'Neill MJ, Mueller PR. Percutaneous abscess drainage in Crohn disease: technical success and short- and long-term outcomes during 14 years. *Radiology* 2002;222(3):645–651
- 14 Yamaguchi A, Matsui T, Sakurai T, et al. The clinical characteristics and outcome of intraabdominal abscess in Crohn's disease. *J Gastroenterol* 2004;39(5):441–448
- 15 Safrit HD, Mauro MA, Jaques PF. Percutaneous abscess drainage in Crohn's disease. *AJR Am J Roentgenol* 1987;148(5):859–862
- 16 Huprich JE, Rosen MP, Fidler JL, et al. ACR Appropriateness Criteria on Crohn's disease. *J Am Coll Radiol* 2010;7(2):94–102
- 17 Sahai A, Bélair M, Gianfelice D, Côté S, Gratton J, Lahaie R. Percutaneous drainage of intra-abdominal abscesses in Crohn's disease: short and long-term outcome. *Am J Gastroenterol* 1997;92(2):275–278
- 18 Muorah M, Hinds R, Verma A, et al. Liver abscesses in children: a single center experience in the developed world. *J Pediatr Gastroenterol Nutr* 2006;42(2):201–206
- 19 Simeunovic E, Arnold M, Sidler D, Moore SW. Liver abscess in neonates. *Pediatr Surg Int* 2009;25(2):153–156
- 20 Lublin M, Bartlett DL, Danforth DN, et al. Hepatic abscess in patients with chronic granulomatous disease. *Ann Surg* 2002;235(3):383–391
- 21 Lee SH, Tomlinson C, Temple M, Amaral J, Connolly BL. Imaging-guided percutaneous needle aspiration or catheter drainage of neonatal liver abscesses: 14-year experience. *AJR Am J Roentgenol* 2008;190(3):616–622
- 22 Rao S, Solaymani-Mohammadi S, Petri WA Jr, Parker SK. Hepatic amebiasis: a reminder of the complications. *Curr Opin Pediatr* 2009;21(1):145–149
- 23 Gyorffy EJ, Frey CF, Silva J Jr, McGahan J. Pyogenic liver abscess. Diagnostic and therapeutic strategies. *Ann Surg* 1987;206(6):699–705
- 24 Liu GJ, Lu MD, Xie XY, et al. Real-time contrast-enhanced ultrasound imaging of infected focal liver lesions. *J Ultrasound Med* 2008;27(4):657–666
- 25 Halvorsen RA Jr, Foster WL Jr, Wilkinson RH Jr, Silverman PM, Thompson WM. Hepatic abscess: sensitivity of imaging tests and clinical findings. *Gastrointest Radiol* 1988;13(2):135–141
- 26 Liu CH, Gervais DA, Hahn PF, Arellano RS, Uppot RN, Mueller PR. Percutaneous hepatic abscess drainage: do multiple abscesses or multiloculated abscesses preclude drainage or affect outcome? *J Vasc Interv Radiol* 2009;20(8):1059–1065
- 27 Rajak CL, Gupta S, Jain S, Chawla Y, Gulati M, Suri S. Percutaneous treatment of liver abscesses: needle aspiration versus catheter drainage. *AJR Am J Roentgenol* 1998;170(4):1035–1039
- 28 Tan YM, Chung AY, Chow PK, et al. An appraisal of surgical and percutaneous drainage for pyogenic liver abscesses larger than 5 cm. *Ann Surg* 2005;241(3):485–490
- 29 Yu SC, Ho SS, Lau WY, et al. Treatment of pyogenic liver abscess: prospective randomized comparison of catheter drainage and needle aspiration. *Hepatology* 2004;39(4):932–938
- 30 Barakate MS, Stephen MS, Waugh RC, et al. Pyogenic liver abscess: a review of 10 years' experience in management. *Aust N Z J Surg* 1999;69(3):205–209
- 31 Hanna RM, Dahniya MH, Badr SS, El-Betagy A. Percutaneous catheter drainage in drug-resistant amoebic liver abscess. *Trop Med Int Health* 2000;5(8):578–581
- 32 Ralls PW, Barnes PF, Johnson MB, De Cock KM, Radin DR, Halls J. Medical treatment of hepatic amebic abscess: rare need for percutaneous drainage. *Radiology* 1987;165(3):805–807
- 33 Blessmann J, Binh HD, Hung DM, Tannich E, Burchard G. Treatment of amoebic liver abscess with metronidazole alone or in combination with ultrasound-guided needle aspiration: a comparative, prospective and randomized study. *Trop Med Int Health* 2003;8(11):1030–1034
- 34 Angel C, Shu T, Green J, Orihuela E, Rodriguez G, Hendrick E. Renal and peri-renal abscesses in children: proposed physio-pathologic mechanisms and treatment algorithm. *Pediatr Surg Int* 2003;19(1–2):35–39
- 35 Chaudhry S, Bolt R. Bilateral renal abscess in a previously healthy 11-year-old girl. *Eur J Pediatr* 2010;169(11):1423–1425
- 36 Kawashima A, Sandler CM, Goldman SM. Imaging in acute renal infection. *BJU Int* 2000;86(Suppl 1):70–79
- 37 Shimizu M, Katayama K, Kato E, Miyayama S, Sugata T, Ohta K. Evolution of acute focal bacterial nephritis into a renal abscess. *Pediatr Nephrol* 2005;20(1):93–95
- 38 Hoddick W, Jeffrey RB, Goldberg HI, Federle MP, Laing FC. CT and sonography of severe renal and perirenal infections. *AJR Am J Roentgenol* 1983;140(3):517–520
- 39 Kao CT, Tsai JD, Lee HC, et al. Right perinephric abscess: a rare presentation of ruptured retrocecal appendicitis. *Pediatr Nephrol* 2002;17(3):177–180
- 40 Wippermann CF, Schofer O, Beetz R, et al. Renal abscess in childhood: diagnostic and therapeutic progress. *Pediatr Infect Dis J* 1991;10(6):446–450
- 41 Gervais DA, Brown SD, Connolly SA, Brec SL, Harisinghani MG, Mueller PR. Percutaneous imaging-guided abdominal and pelvic abscess drainage in children. *Radiographics* 2004;24(3):737–754
- 42 Siegel JF, Smith A, Moldwin R. Minimally invasive treatment of renal abscess. *J Urol* 1996;155(1):52–55
- 43 Benifla M, Weizman Z. Acute pancreatitis in childhood: analysis of literature data. *J Clin Gastroenterol* 2003;37(2):169–172
- 44 Stamatakis M, Stefanaki C, Kontzoglou K, Stergiopoulos S, Giannopoulos G, Safioleas M. Walled-off pancreatic necrosis. *World J Gastroenterol* 2010;16(14):1707–1712
- 45 King LR, Siegel MJ, Balfe DM. Acute pancreatitis in children: CT findings of intra- and extrapancreatic fluid collections. *Radiology* 1995;195(1):196–200
- 46 Yachha SK, Chetri K, Saraswat VA, et al. Management of childhood pancreatic disorders: a multidisciplinary approach. *J Pediatr Gastroenterol Nutr* 2003;36(2):206–212
- 47 Beger HG, Rau BM. Severe acute pancreatitis: clinical course and management. *World J Gastroenterol* 2007;13(38):5043–5051
- 48 Ocampo C, Zandalazini H, Kohan G, Silva W, Szelagowsky C, Oría A. Computed tomographic prognostic factors for predicting local complications in patients with pancreatic necrosis. *Pancreas* 2009;38(2):137–142
- 49 Freeny PC, Hauptmann E, Althaus SJ, Traverso LW, Sinanan M. Percutaneous CT-guided catheter drainage of infected acute necrotizing pancreatitis: techniques and results. *AJR Am J Roentgenol* 1998;170(4):969–975
- 50 Vernacchia FS, Jeffrey RB Jr, Federle MP, et al. Pancreatic abscess: predictive value of early abdominal CT. *Radiology* 1987;162(2):435–438
- 51 Lee MJ, Wittich GR, Mueller PR. Percutaneous intervention in acute pancreatitis. *Radiographics* 1998;18(3):711–724; discussion 728
- 52 Amundson GM, Towbin RB, Mueller DL, Seagram CG. Percutaneous transgastric drainage of the lesser sac in children. *Pediatr Radiol* 1990;20(8):590–593

- 53 Burnweit C, Wesson D, Stringer D, Filler R. Percutaneous drainage of traumatic pancreatic pseudocysts in children. *J Trauma* 1990; 30(10):1273–1277
- 54 vanSonnenberg E, Wittich GR, Casola G, et al. Percutaneous drainage of infected and noninfected pancreatic pseudocysts: experience in 101 cases. *Radiology* 1989;170(3 Pt 1):757–761
- 55 Mortelé KJ, Girshman J, Szejnfeld D, et al. CT-guided percutaneous catheter drainage of acute necrotizing pancreatitis: clinical experience and observations in patients with sterile and infected necrosis. *AJR Am J Roentgenol* 2009;192(1):110–116
- 56 Seewald S, Ang TL, Richter H, et al. Long-term results after endoscopic drainage and necrosectomy of symptomatic pancreatic fluid collections. *Dig Endosc* 2012;24(1):36–41
- 57 Choudhury SR, Debnath PR, Jain P, et al. Conservative management of isolated splenic abscess in children. *J Pediatr Surg* 2010;45(2):372–375
- 58 Ramakrishnan MR, Sarathy TK, Balu M. Percutaneous drainage of splenic abscess: case report and review of literature. *Pediatrics* 1987;79(6):1029–1031
- 59 Ooi LL, Leong SS. Splenic abscesses from 1987 to 1995. *Am J Surg* 1997;174(1):87–93
- 60 Chiang IS, Lin TJ, Chiang IC, Tsai MS. Splenic abscesses: review of 29 cases. *Kaohsiung J Med Sci* 2003;19(10):510–515
- 61 Llenas-García J, Fernández-Ruiz M, Caurcel L, Enguita-Valls A, Vila-Santos J, Guerra-Vales JM. Splenic abscess: a review of 22 cases in a single institution. *Eur J Intern Med* 2009;20(5):537–539
- 62 Kang M, Saxena AK, Gulati M, Suri S. Ultrasound-guided percutaneous catheter drainage of splenic abscess. *Pediatr Radiol* 2004; 34(3):271–273
- 63 Cívardi G, Di Candio G, Giorgio A, et al. Ultrasound guided percutaneous drainage of abdominal abscesses in the hands of the clinician: a multicenter Italian study. *Eur J Ultrasound* 1998; 8(2):91–99
- 64 Chang KC, Chuah SK, Changchien CS, et al. Clinical characteristics and prognostic factors of splenic abscess: a review of 67 cases in a single medical center of Taiwan. *World J Gastroenterol* 2006; 12(3):460–464
- 65 Thanos L, Dailiana T, Papaioannou G, Nikita A, Koutrouvelis H, Kelekis DA. Percutaneous CT-guided drainage of splenic abscess. *AJR Am J Roentgenol* 2002;179(3):629–632
- 66 Bisharat N, Omari H, Lavi I, Raz R. Risk of infection and death among post-splenectomy patients. *J Infect* 2001;43(3): 182–186
- 67 Lucey BC, Boland GW, Maher MM, Hahn PF, Gervais DA, Mueller PR. Percutaneous nonvascular splenic intervention: a 10-year review. *AJR Am J Roentgenol* 2002;179(6):1591–1596
- 68 Zerem E, Bergsland J. Ultrasound guided percutaneous treatment for splenic abscesses: the significance in treatment of critically ill patients. *World J Gastroenterol* 2006;12(45):7341–7345
- 69 Atkinson GO Jr, Kodroff MB, Gay BB Jr, Ricketts RR. Adrenal abscess in the neonate. *Radiology* 1985;155(1):101–104
- 70 Diepstraten SC, Zwaveling S, Beek FJ. Diagnosis and subsequent US-guided percutaneous drainage of an adrenal abscess in a 5-week-old infant. *Pediatr Radiol* 2012;42(9):1126–1129
- 71 Paterson A. Adrenal pathology in childhood: a spectrum of disease. *Eur Radiol* 2002;12(10):2491–2508
- 72 Hogan MJ, Hoffer FA. Biopsy and drainage techniques in children. *Tech Vasc Interv Radiol* 2010;13(4):206–213
- 73 Coté CJ, Wilson S; American Academy of Pediatrics; American Academy of Pediatric Dentistry; Work Group on Sedation. Guidelines for monitoring and management of pediatric patients during and after sedation for diagnostic and therapeutic procedures: an update. *Pediatrics* 2006;118(6):2587–2602
- 74 American Society of Anesthesiologists Task Force on Sedation and Analgesia by Non-Anesthesiologists. Practice guidelines for sedation and analgesia by non-anesthesiologists. *Anesthesiology* 2002; 96(4):1004–1017
- 75 Coley BD, Hogan MJ. Image-guided interventions in neonates. *Eur J Radiol* 2006;60(2):208–220
- 76 Lorenz JM, Funaki BS, Ray CE Jr, et al. ACR Appropriateness Criteria on percutaneous catheter drainage of infected fluid collections. *J Am Coll Radiol* 2009;6(12):837–843
- 77 Matalon TA, Silver B. US guidance of interventional procedures. *Radiology* 1990;174(1):43–47
- 78 vanSonnenberg E, Wittich GR, Edwards DK, et al. Percutaneous diagnostic and therapeutic interventional radiologic procedures in children: experience in 100 patients. *Radiology* 1987;162(3): 601–605
- 79 vanSonnenberg E, Wittich GR, Casola G, et al. Complicated pancreatic inflammatory disease: diagnostic and therapeutic role of interventional radiology. *Radiology* 1985;155(2):335–340
- 80 Rao S, Hogan MJ. Trocar transrectal abscess drainage in children: a modified technique. *Pediatr Radiol* 2009;39(9):982–984
- 81 Beland MD, Gervais DA, Levis DA, Hahn PF, Arellano RS, Mueller PR. Complex abdominal and pelvic abscesses: efficacy of adjunctive tissue-type plasminogen activator for drainage. *Radiology* 2008; 247(2):567–573
- 82 Harisinghani MG, Gervais DA, Hahn PF, et al. CT-guided transgluteal drainage of deep pelvic abscesses: indications, technique, procedure-related complications, and clinical outcome. *Radiographics* 2002;22(6):1353–1367
- 83 Mueller PR, Ferrucci JT Jr, Simeone JF, et al. Lesser sac abscesses and fluid collections: drainage by transhepatic approach. *Radiology* 1985;155(3):615–618
- 84 Cahill AM, Baskin KM, Kaye RD, Fitz CR, Towbin RB. Transgluteal approach for draining pelvic fluid collections in pediatric patients. *Radiology* 2005;234(3):893–898
- 85 Gervais DA, Hahn PF, O'Neill MJ, Mueller PR. CT-guided transgluteal drainage of deep pelvic abscesses in children: selective use as an alternative to transrectal drainage. *AJR Am J Roentgenol* 2000;175(5):1393–1396
- 86 vanSonnenberg E, Ferrucci JT Jr, Mueller PR, Wittenberg J, Simeone JF. Percutaneous drainage of abscesses and fluid collections: technique, results, and applications. *Radiology* 1982;142(1):1–10
- 87 Jaffe RB, Arata JA Jr, Matlak ME. Percutaneous drainage of traumatic pancreatic pseudocysts in children. *AJR Am J Roentgenol* 1989;152(3):591–595
- 88 Pereira JK, Chait PG, Miller SF. Deep pelvic abscesses in children: transrectal drainage under radiologic guidance. *Radiology* 1996; 198(2):393–396
- 89 Butch RJ, Mueller PR, Ferrucci JT Jr, et al. Drainage of pelvic abscesses through the greater sciatic foramen. *Radiology* 1986; 158(2):487–491
- 90 Alexander AA, Eschelman DJ, Nazarian LN, Bonn J. Transrectal sonographically guided drainage of deep pelvic abscesses. *AJR Am J Roentgenol* 1994;162(5):1227–1230; discussion 1231–1232
- 91 Haaga JR, Nakamoto D, Stellato T, et al. Intracavitary urokinase for enhancement of percutaneous abscess drainage: phase II trial. *AJR Am J Roentgenol* 2000;174(6):1681–1685
- 92 Goldberg MA, Mueller PR, Saini S, et al. Importance of daily rounds by the radiologist after interventional procedures of the abdomen and chest. *Radiology* 1991;180(3):767–770