Quality Improvement Guidelines for Pediatric Abscess and Fluid Drainage

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ABBREVIATION

INR = International Normalized Ratio

PREAMBLE

The membership of the Society of Interventional Radiology (SIR) Standards of Practice Committee represents experts in a broad spectrum of interventional procedures from the private and academic sectors of medicine. Generally Standards of Practice Committee members dedicate the vast majority of their professional time to performing interventional procedures; as such, they represent a valid broad expert constituency of the subject matter under consideration for standards production.

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METHODOLOGY

SIR produces its Standards of Practice documents using the following process. Standards documents of relevance and timeliness are conceptualized by the Standards of Practice Committee members. A recognized expert is identified to serve as the principal author for the standard. Additional authors may be assigned dependent upon the magnitude of the project.

An in-depth literature search is performed by using electronic medical literature databases. Then, a critical review of peer-reviewed articles is performed with regard to the study methodology, results, and conclusions. The qualitative weight of these articles is assembled into an evidence table, which is used to write the document such that it contains evidence-based data with respect to content, rates, and thresholds.

When the evidence of literature is weak, conflicting, or contradictory, consensus for the parameter is reached by a minimum of 12 Standards of Practice Committee members using a modified Delphi consensus method (Appendix) (1). For purposes of these documents, consensus is defined as 80% Delphi participant agreement on a value or parameter.

The draft document is critically reviewed by the Standards of Practice Committee members, either by telephone conference calling or face-to-face meeting. The finalized draft from the Committee is sent to the SIR membership for further input/criticism during a 30-day comment period. These comments are discussed by the Standards of Practice Committee, and appropriate revisions made to create the finished standards document. Before its publication, the document is endorsed by the SIR Executive Council.

PEDIATRIC ABSCESS AND FLUID DRAINAGE

General Considerations

Image-guided abscess and fluid drainage is a mainstay of a pediatric interventional radiology practice, and is the treatment of choice for many conditions. As in an adult practice, primary and postoperative fluid collections in nearly every organ system have been successfully treated by image-guided techniques, resulting in improved patient care (2–37). Although the majority of techniques in children are similar to those in adults, there are several important differences. The etiologies of abscesses and fluid collections may be different (4–38). Radiation protection awareness is paramount in the pediatric population and requires modification of technique (39–42). Children have different sedation and anesthetic requirements (43–45). Children's small size has both advantages and disadvantages, and may require/allow for alteration of procedural techniques. Complications may be similar, but specific problems may be seen with different prevalence.

Definitions

As with the adult standards, "percutaneous drainage is defined as the placement of a catheter using imaging guidance to provide continuous drainage of a fluid collection. This includes localization of the collection and placement and maintenance of the drainage catheter(s). This may be performed during a single session or as a staged procedure during multiple sessions. Percutaneous aspiration is defined as the evacuation of a fluid collection by using a catheter or needle, with removal of the catheter or needle immediately after the aspiration" (2,3,37).

Indications

Because of the variability in the presentation of abscesses and fluid collections, the indications for drainage or aspiration must be stated in general terms. These general indications include the presence of a fluid collection, and one of the following (2,3):

1. Suspicion that the collection is infected;
2. Need for fluid characterization; or
3. Suspicion that the collection is producing symptoms sufficient to warrant drainage.

Most collections are found after an imaging study is performed, when their existence is suspected from physical examination and/or laboratory studies. Additional studies may be required to confirm the presence or nature of the fluid collection and to evaluate the feasibility of drainage.

Diagnostic aspiration may be the only means of determining that a collection is infected, as physical examination and laboratory studies may be conflicting or nondiagnostic. If infection is suspected during aspiration, a drainage catheter may be placed.

Although image-guided aspiration and drainage can almost universally be performed, the potential complications, as well as the medical and surgical alternatives, should be weighed with respect to the potential benefit. Potential complicating factors such as coagulopathy or complex drainage routes (eg, deep abscess with bowel or other organs interposed between the site of access and the abscess) must be recognized, evaluated, and corrected if necessary and if possible. Multiple abscesses may be better approached by surgery, although practice may be evolving toward treatment with multiple percutaneous drains (6).

Etiologies

Fluid collections and abscesses can occur anywhere in the body. In children, the most common cause of intraabdominal abscesses is appendicitis (4–14,46–49). Children with appendicitis are more likely to present with perforation and abscesses than adults (4,5). Primary drainage is frequently performed as an alternative to initial surgery, which allows the patient to recover from their acute infection (4–6,10,12). Some surgeons subsequently perform laparoscopic surgery to remove the appendix (10). Postoperative abscesses also occur after appendectomy and other abdominal surgeries; image-guided procedures in these situations are a valuable option, as surgical alternatives carry significant morbidity in the postoperative abdomen (4–9,11–14,46–49). Other etiologies for pediatric abdominal fluid collections include Crohn disease, cerebrospinal fluid pseudocysts, abscesses from necrotizing enterocolitis, posttraumatic collections, acalculous cholecystitis, and various causes that are encountered in the adult population (4,5,15–17).

Image-guided percutaneous drainage of pleural effusions and empyemas is commonly performed in children, often with the instillation of thrombolytic agents (18–28). Pulmonary abscesses and infected congenital cystic adenomatoid malformations can also be drained via percutaneous catheters (29–32).

Soft tissue and musculoskeletal drainage indications include septic joints/joint effusions, abscesses from cellulitis and other soft-tissue infections, aspiration of suspected osteomyelitis, and infected congenital cystic lesions such as lymphatic malformations, thyroglossal duct cysts, and branchial cleft cysts (33–36,38). The drainage of congenital cystic lesions may also be the initial step in performing therapeutic sclerotherapy as a definitive treatment (34).

Preprocedural Evaluation

Most collections are identified by an imaging study. It is important that these imaging studies be tailored to the patients' symptoms, possible diagnoses, and potential treatment options including the best access approach. Ultrasound (US) should be used whenever possible. This will spare the patient potential radiation exposure, which is a critical concern in children. If a computed tomography (CT) scan is the study of choice, it should be performed with the lowest radiation dose possible, and be protocoled to answer all the necessary questions listed earlier in a single study.

Before a potential drainage procedure is performed, it is necessary to carefully review the indications and communicate with the referring service to ensure that the patient is receiving the most appropriate treatment. In general, given the procedural, sedation, and radiation risks to children, more time is spent in communication with referring teams, consulting services, and the family before procedures than for comparable adult procedures. A detailed informed consent must be obtained from the parents or guardians (50).

Preprocedural laboratory tests such as an International Normalized Ratio (INR) and platelet count may be helpful in the patient with a suspected bleeding tendency, and are required in a patient with a known bleeding disorder. Additionally, if an organ will be traversed such as transhepatic access for a cholecystostomy tube, these laboratory tests should be obtained. If the patient is coagulopathic, oral vitamin K, fresh frozen plasma, cryoprecipitate, or platelet transfusion may be indicated. In the case of transfusions, it is important that they be provided immediately before or during the case to optimize protective effects of the transfusion. General guidelines are that elective procedures can be performed safely with a platelet count of more than 50,000 platelets/μL and an INR lower than 1.2, with an INR lower than 1.5 preferred for urgent cases (51).

The administration of intravenous antibiotics may be indicated, as manipulation of an infected collection may precipitate septicemia. The use and type of antibiotics should be determined based on the expected pathogens and clinical need (52).

Radiation Protection

Children are more radiation-sensitive than adults and have a longer lifespan during which to manifest radiation-induced cancers (39,42,53). Although abscess drainage procedures are not usually one of the procedures in pediatric interventional radiology associated with high radiation dose, lengthy or repeated procedures may nevertheless result in significant radiation exposure (41,54). In addition, many abscesses are located near radiation-sensitive organs such as the gonads (in the case of pelvic abscess), thyroid, breast, or orbits in children. It is prudent and important to use appropriate radiation safety techniques when performing pediatric interventional procedures (39–42). As an additional benefit, reducing the radiation exposure to the patient also reduces exposure to operator and ancillary personnel, for whom the largest source of radiation is scatter from the patient (55).

Many pediatric patients are smaller than adults, which reduces the total amount of scatter dose. However, other factors increase operator dose, such as magnification use during certain procedures, which generally increases patient and operator dose; the small size of the patient may require the operator to stand closer to the x-ray source and may make it difficult to keep their hands out of the primary beam during certain portions of the procedure.

Some techniques for decreasing patient radiation dose include substituting US for CT or fluoroscopy when feasible, using reduced-dose pediatric CT protocols, using the last image hold feature to view anatomy rather than live fluoroscopy, using pulsed fluoroscopy, tightly collimating to the area of interest, minimizing the use of magnification, and optimally positioning the patient away from the x-ray source (39,41).

Sedation and Anesthesia

Most children will not be able to cooperate with an interventional procedure without some form of sedation or anesthesia to ensure a successful and safe outcome (14,43–45). Choice and route of sedation must be decided in those patients requiring this support. Although select situations and patients may require only local anesthetic administration, most will likely require a higher level of sedation than in adults, and possibly general anesthesia. Topical anesthetic creams are useful adjuncts for patients undergoing conscious sedation, to lessen the painful sensation caused by local anesthetic infiltration. The interventionalist must help plan for this, and decide what level of support the patient needs, given patient age and pain tolerance, difficulty and duration of the procedure, and expected level of procedural pain. General anesthesia may be preferred when airway management is an issue, or in patients in whom previous attempts at sedation have failed. Moderate sedation can be performed under the supervision of medical personnel trained in pediatric sedation, whereas deep sedation may be aided by the use of a dedicated sedation service or the anesthesia department.

Patient Care Issues

Maintaining the appropriate homeostatic and monitoring environment during the procedure is of paramount importance. As young children, especially those younger than 2 years of age, are very susceptible to ambient temperature changes, temperature monitoring is recommended. Some procedures in critically ill neonates may best be performed in the neonatal or pediatric intensive care unit to maximize patient support. Patient size-specific leads and probes for routine electrocardiography, blood pressure, and respiratory monitoring are required, with proper padding of pressure points to minimize nerve palsies (56,57). Appropriate patient immobilization for safety is also important.

Contraindications

It is mandatory that a discussion with the patient and/or family and referring physicians takes place before the procedure. As discussed previously, coagulopathies should be evaluated and corrected if possible. If access is not possible without traversing organs such as bowel, a trial of antibiotic therapy, simple needle aspiration, or surgical treatment are options. As with all procedures, the benefits of drainage should be weighed with regard to the patient's overall clinical status.

Image Guidance and Approach

The choice of imaging used for guidance is based on which modality provides the safest procedure with the highest likelihood of success. US guidance is by far the most common in children (4–6,8,13–19,25,33–36,38,58–60). The smaller body habitus of most children allows for better visualization during imaging guidance. The multiplanar capability of freehand imaging allows for many choices of access site and trajectory. As discussed previously, the use of US eliminates radiation exposure. However, US may not be the optimal imaging modality in certain circumstances. The presence of intervening air or bone limits the effectiveness of US. If either air or bone is between the transducer and the collection, CT guidance may be required. In obese patients, US may not provide adequate visualization. In addition, certain techniques and situations may be better suited to alternative guidance. Transgluteal drainage can be performed best with CT guidance (9,11,58). Drainage of loculated or complex pneumothoraces or pneumatoceles may be better achieved with CT or fluoroscopic guidance.

Pediatric patients range in weight from less than 600 g to greater than 200 kg. This diversity requires that many different transducers be available, and the US machine must be of sufficient quality to image all these patients.

Although fluoroscopy is typically used during guide wire placement, tract dilation, and catheter deployment, US may be substituted to eliminate radiation exposure.

Alternative percutaneous approaches are possible when imaging demonstrates a potential anatomic challenge such as interposed organs, bowel, or blood vessels, or when another approach is easier to perform. For deep pelvic abscesses, transgluteal and transrectal approaches are both possible in children, with the choice of approach dependent on the interventionalist (7–9,11,13,14,58–60). Transrectal drainage in children is usually similar to that in adults (8,13,14,59,60). However, if the child is small, the endocavitary probe may not fit into the rectum. For these patients, the imaging is typically transabdominal (8,59,60). The advancement of the needle or catheter through the rectum into the abscess can be visualized through the bladder as an acoustic window. Techniques have been described to protect the rectal mucosa from the needle or catheter during advancement (8,59,61).

Procedure

Percutaneous drain insertion follows the technique of surgical drainage, whereby the route of drainage should avoid normal adjacent structures such as nerve bundles, blood vessels, bowel, pleura, and lung. Small collections ($<$ 3 cm in diameter) may be aspirated, whereas larger abscesses will usually require indwelling drain placement. Catheter insertion can be performed by using a trocar or Seldinger technique (59,61). In the trocar technique, the catheter is loaded onto a needle, which, with imaging guidance, is used to puncture the abscess cavity (59,61). The catheter is then advanced over the needle into the cavity. The main advantage of the trocar technique is that it is quick and essentially involves one step. This technique can therefore be used in patients who are not deeply sedated, as a bedside technique in critically ill patients, and for a large fluid collection with a straightforward access trajectory. The main disadvantage is that the trocar technique can result in a less-than-optimal catheter position and increased complication risk if the correct trajectory is not chosen. Risks are minimized in the hands of experienced operators, and when the trocar technique is used in conjunction with fluoroscopy (61). In the pediatric population, it is an effective technique when used for transrectal abscess drain insertion (59).

In the Seldinger technique, the fluid collection is punctured with a needle by using image guidance. Typically, an appropriately sized single-wall needle or sheathed needle is used that allows for passage of an 0.035-inch guide wire into the fluid collection. If a 21-gauge needle/0.018-inch guide wire combination is used for initial access, exchange to an 0.035-inch guide wire will be required. After serial dilation of the tract, the catheter is placed over the wire and formed within the collection using US or fluoroscopic guidance. Use of a small-caliber needle for initial puncture is of value when the window to avoid nearby structures is small, resulting in a difficult access. The Seldinger technique is more controlled and can result in less risk to nearby structures, but becomes difficult when there is increased tissue mobility (eg, nephrostomy insertion, suprapubic catheter insertion, and drainage of lymphatic malformations). It can also result in more leakage of body fluids around the indwelling wire during dilator/catheter exchange, potentially causing contamination of the field and reduction in size of the abscess cavity, making catheter insertion more difficult (7). It can be more painful as a result of the number of steps involved, and consequently adequate sedation is essential. The Seldinger technique combined with image guidance will ensure proper catheter placement and positioning. In the thorax, CT or fluoroscopy may be required, as the presence of air may limit the effectiveness of US.

Typically, depending on the size of the patient and the characteristics of the collection, 6–14-F catheters can be successfully placed by using a percutaneous route. Locking-loop drainage catheters are often used to prevent catheter dislodgment. In very young children and for drainage of small collections, smaller French size catheters and a smaller diameter of the locking loop are important, as a standard-diameter locking loop may not form properly. After placement, the catheter is then secured with an anchoring suture and/or an adhesive device. Catheter surveillance and maintenance should include output monitoring, and many operators will flush the catheter with 3–10 mL of sterile 0.9% saline solution every 8–12 hours to maintain patency and insure drainage. Depending on the size of the collection, the administration of intracavitary tissue plasminogen activator in a dose ranging from 2 mg to 10 mg mixed with 20–50 mL of normal saline

Table 1. Success Rates and Thresholds

Outcome	Suggested Threshold Value (%)
Successful diagnostic fluid aspiration	
Aspiration of adequate fluid for diagnostic characterization	95
Successful drainage	
Curative and partial success	85

solution can be effective in facilitating drainage of a complex collection. Therapy can be performed on an as-needed basis or on a set regimen (eg, twice daily for a few days) with good result (62,63). Alternatively, the drain can be exchanged for a larger size over a guide wire.

Success Rates and Thresholds

Successful diagnostic fluid aspiration is defined as the aspiration of material sufficient for diagnosis. The suggested threshold for aspiration of adequate fluid for diagnostic characterization is 95% (3,37). Success rates and thresholds are summarized in **Table 1**.

Curative drainage is defined as complete resolution of infection requiring no further operative intervention. Curative drainage has been achieved in more than 80% of patients. Partial success is defined as adequate drainage of the abscess with surgery subsequently performed to repair an underlying problem or as temporizing drainage performed to stabilize the patient's condition before surgery. Partial success occurs in 5%–10% of patients (3). Failure occurs in 5%–10% and recurrence in 5%–10% (3). These results are similar for abdominal and chest drainage procedures. These success rates will depend on the proportion of collections drained in patients with relative contraindications, on the complexity of the collection, and on the severity of the underlying medical problems. The suggested threshold for curative and partial success is 85% (**Table 1**) (3).

Drainage of Infected Collections. Because of the variability of the types of infected collections, the success rate of drainage will be highly variable, and it is not believed that a specific threshold for success in drainage of infected collections can be set.

Complications

Published rates for individual types of complications in children are limited and based on relatively few patients. In addition, any incidence of complications is highly dependent on patient selection. Although this document has detailed multiple differences between the pediatric and adult population, we believe extrapolation of the quality assurance guidelines from the adult experience is appropriate (**Table 2**) (2,3). It should be recognized that a single complication can cause a rate to cross above a complication-specific threshold when the complication occurs in a small series of patients. In this situation, the overall procedure threshold is more appropriate for use in a quality-improvement program. In adults, the overall incidence of complications is estimated at approximately 10% (2,3). Definitions of procedural complications are listed in **Table 3**.

Complications can be directly procedure-related or systemic. Bleeding can occur with any needle placement. The access window can be small in children, and injury to any interposed artery or vein can occur, eg, puncture of the inferior epigastric artery is a risk with right lower quadrant drainages such as appendiceal abscess drainage. US can help identify the position of this or any other interposed artery, and help avoid inadvertent puncture.

Proper preprocedural imaging and planning and real-time image guidance with US reduces, but does not entirely eliminate, the risk of inadvertent bowel or other organ injury. Sepsis is a risk, particularly with suboptimal antibiotic coverage. Rupture of the abscess wall can occur during a drainage procedure because of an immature abscess wall or excessive guide wire manipulation. Free spillage of pus into the surrounding cavity/space can cause sepsis in the patient.

Because pediatric patients typically need a higher level of sedation for a safe and successful procedure, complications from sedation and anesthesia may occasionally occur. Although the risks of general anesthesia are low, they can be major, especially in patients with compromised cardiopulmonary function (43,44). The majority of complications seen with general anesthesia in these patients are minor, with postoperative nausea and vomiting the most common issue. Careful communication with anesthesiologists before draining intraparenchymal lung abscesses is very important because of the risk of dissemination of the abscess contents into the ipsilateral, and even the contralateral, lung.

Table 2. Published Complication Rates and Suggested Thresholds

Specific Major Complication	Rate (%)	Suggested Threshold (%)
Septic shock	1–2	4
Bacteremia requiring significant new intervention	2–5	10
Hemorrhage requiring transfusion	1	2
Superinfection (includes infection of sterile fluid collection)	1	2
Bowel transgression requiring intervention	1	2
Pleural transgression requiring intervention (abdominal procedures)	1	2
Pleural transgression requiring additional intervention (chest procedures)	2–10	20

Table 3. SIR Classification of Complications

Class	Result
Minor complications	
A	No therapy, no consequence
B	Nominal therapy, no consequence; includes overnight admission for observation only
Major complications	
C	Require major therapy, minor hospitalization (< 48 h)
D	Require major therapy, unplanned increase in level of care, prolonged hospitalization (> 48 h)
E	Permanent adverse sequelae
F	Death

SUMMARY

Image-guided drainage of abscesses and fluid collections is a valuable tool in the treatment of pediatric patients. It may obviate surgery or optimize the child's clinical condition for subsequent surgery. Compared with adults, several differences exist in terms of etiology, risks (especially radiation exposure), preprocedural imaging and planning, technical considerations, support issues such as sedation, and complications. Knowledge of these differences is important in the planning and treatment of these patients. In addition, a quality improvement plan can be used to assess practice performance.

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REFERENCES

1. Fink A, Kosefcoff J, Chassin M et al. Consensus methods: characteristics and guidelines for use. Am J Public Health 1984; 74:979–983.
2. Bakal CW, Sacks D, Burke DR, et al. Quality improvement guidelines for adult percutaneous abscess and fluid drainage. J Vasc Interv Radiol 2003; 14(suppl):S223–S225.
3. Wallace MJ, Chin KW, Fletcher TB, et al. Quality improvement guidelines for percutaneous drainage/aspiration of abscess and fluid collections. J Vasc Interv Radiol 2010; 21:431–435.
4. Hogan MJ. Appendiceal abscess drainage. Tech Vasc Interv Radiol 2003; 6:205–214.
5. Hogan MJ, Hoffer FA. Biopsy and drainage techniques in children. Tech Vasc Interv Radiol 2010; 13:206–213.
6. 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; 38:661–668.
7. Gervais DA, Brown SD, Connolly SA, et al. Percutaneous imaging guided abdominal and pelvic abscess drainage in children. Radiographics 2004; 24:737–754.
8. Pereira JK, Chait PG, Miller SF: Deep pelvic abscesses in children: transrectal drainage under radiologic guidance. Radiology 1996; 198:393–396.
9. Gervais DA, Hahn PF, O'Neill MJ, Mueller P: CT-guided transgluteal drainage of deep pelvic abscesses in children: selective uses as an alternative to transrectal drainage. AJR Am J Roentgenol 2000; 175: 1393–1396.
10. Roach JP, Partrick DA, Bruny JL, Allshouse MJ, Karrer FM, Ziegler MM. Complicated appendicitis in children: a clear role for drainage and delayed appendectomy. Am J Surg 2007; 194:769–772.
11. Cahill AM, Baskin KM, Kaye RD, Fitz CR, Towbin RB. Transgluteal approach for draining pelvic fluid collections in pediatric patients. Radiology 2005; 234:893–898.
12. Curran TJ, Muenchow SK. The treatment of complicated appendicitis in children using peritoneal drainage: results from a public hospital. J Pediatr Surg 1993; 28:204–208.
13. Chung T, Hoffer FA, Lund DP. Transrectal drainage of deep pelvic abscesses in children using a combined transrectal sonographic and fluoroscopic guidance. Pediatr Radiol. 1996; 26:874–878.
14. Koral K, Derinkuyu B, Gargan L, Lagomarsino EM, Murphy JT. Transrectal ultrasound and fluoroscopy-guided drainage of deep pelvic collections in children. J Pediatr Surg 2010; 45:513–518.
15. Coley BD, Shiels WE II, Elton S, Murakami JW, Hogan MJ. Sonographically guided aspiration of cerebrospinal fluid pseudocysts in children and adolescents. AJR Am J Roentgenol 2004; 83:1507–1510.
16. Sidhu MK, Hogan MJ, Shaw DW, Burdick T. Interventional radiology for paediatric trauma. Pediatr Radiol 2009; 39:506–515.
17. Hultman CS, Herbst CA, McCall JM, Mauro MA. The efficacy of percutaneous cholecystostomy in critically ill patients. Am Surg 1996; 62: 263–269.
18. Feola GP, Shaw CA, Coburn L. Management of complicated parapneumonic effusions in children. Tech Vasc Interv Radiol. 2003; 6:197–204.
19. Hogan MJ, Coley BC. Interventional radiology treatment of empyema and lung abscesses. Paediatr Respir Rev 2008; 9:77–84.
20. Hawkins JA, Scaife ES, Hillman ND, Feola GP. Current treatment of pediatric empyema. Semin Thorac Cardiovasc Surg 2004; 16:196–200.
21. Cremonesini DA, Thomson AH. How should we manage empyema: antibiotics alone, fibrinolytics, or primary video-assisted thoracoscopic surgery (VATS)? Semin Respir Crit Care Med 2007; 28:322–332.
22. Jaffé A, Balfour-Lynn IM. Management of empyema in children. Pediatr Pulmonol 2005; 40:148–56.
23. Stefanutti G, Ghirardo V, Barbato A, Gamba P. Evaluation of a pediatric protocol of intrapleural urokinase for pleural empyema: a prospective study. Surgery 2010; 148:589–594.
24. Bianchini MA, Ceccarelli PL, Repetto P, et al. Once-daily intrapleural urokinase treatment of complicated parapneumonic effusion in pediatric patients. Turk J Pediatr 2010; 52:274–277.
25. Gates RL, Hogan M, Weinstein S, Arca MJ. Drainage, fibrinolytics, or surgery: a comparison of treatment options in pediatric empyema. J Pediatr Surg 2004; 39:1638–1642.
26. Mahant S, Cohen E, Weinstein M, Wadhwa A. Video-assisted thorascopic surgery vs chest drain with fibrinolytics for the treatment of pleural empyema in children: a systematic review of randomized controlled trials. Arch Pediatr Adolesc Med 2010; 164:201–203.
27. St Peter SD, Tsao K Harrison C, et al. Thoracoscopic decortication vs tube thoracostomy with fibrinolysis for empyema in children: a prospective, randomized trial. J Pediatr Surg 2009; 44:106–111.
28. Sonnappa S, Cohen G, Owens CM, et al. Comparison of urokinase and video-assisted thoracoscopic surgery for treatment of childhood empyema. Am J Respir Crit Care Med 2006; 174:221–227.
29. Patradoon-Ho P, Fitzgerald DA. Lung abscess in children. Paediatr Respir Rev 2007; 8:77–84.
30. Lorenzo RL, Bradford BF, Black J, Smith CD. Lung abscesses in children: diagnostic and therapeutic needle aspiration. Radiology 1985; 157: 79–80.
31. Ball BS, Bisset GS, Towbin RB. Percutaneous drainage of chest abscesses in children. Radiology 1989; 171:431–434.
32. Hoffer FA, Bloom DA, Colin AA, Fishman SJ. Lung abscess versus necrotizing pneumonia: implications for interventional therapy. Pediatr Radiol 1999; 29:87–91.
33. Aliabadi P, Baker ND, Jaramillo D. Hip arthrography, aspiration, block, and bursography. Radiol Clin North Am 1998; 36:673–690.
34. Shiels WE II, Kang DR, Murakami JW, Hogan MJ, Wiet GJ. Percutaneous treatment of lymphatic malformations. Otolaryngol Head Neck Surg 2009; 141:219–224.
35. Zawin JK, Hoffer FA, Rand FF, Teele RL. Joint effusion in children with an irritable hip: US diagnosis and aspiration. Radiology 1993; 187:459–463.
36. Zamzam MM. The role of ultrasound in differentiating septic arthritis from transient synovitis of the hip in children. J Pediatr Orthop B 2006; 15:418–422.
37. American College of Radiology/Society of Interventional Radiology. ACR-SIR practice guideline for specifications and performance of image-guided percutaneous drainage/aspiration of abscesses and fluid collections (PDAFC) in adults. Available at http://www.acr.org/~/media/ACR/Documents/PGTS/guidelines/PDAFC.pdf. Accessed June 11, 2012.
38. Rozovsky K, Hiller N, Koplewitz BZ, Simanovsky N. Does CT have an additional diagnostic value over ultrasound in the evaluation of acute inflammatory neck masses in children? Eur Radiol 2010; 20:484–490.
39. Sidhu M, Strauss KJ, Connolly MB, et al. Radiation safety in pediatric interventional radiology. Tech Vasc Interv Radiol 2010; 13:158–166.
40. Health Risks from Exposure to Low Levels of Ionizing Radiation: BEIR VII Phase 2. Washington DC: Committee to Assess Health Risks from Exposure to Low Levels of Ionizing Radiation, 2006;1–32.
41. Stecker MS, Balter S, Towbin RB, et al. Guidelines for patient radiation dose management. J Vasc Interv Radiol 2009; 20(suppl):S263–S273.
42. Hall EJ. Radiation biology for pediatric radiologists. Pediatr Radiol 2009; 39(suppl 1):S57–S64.
43. Cravero JP, Blike GT, Beach M, et al. Incidence and nature of adverse events during pediatric sedation/anesthesia for procedures outside the operating room: report from the Pediatric Sedation Research Consortium. Pediatrics 2006; 118:1087–1096.
44. Mason KP. Pediatric procedures in interventional radiology. Int Anesthesiol Clin 2009; 47:35–43.
45. American College of Radiology/Society of Interventional Radiology. ACR-SIR practice guideline for sedation/analgesia. Available at http://www.acr.org/~/media/ACR/Documents/PGTS/guidelines/Adult_Sedation.pdf, Accessed June 11, 2012.

46. Lasson A, Lundagards J, Loren I, Nilsson PE. Appendiceal abscesses: primary percutaneous drainage and selective interval appendicectomy. Eur J Surg 2002; 168:264–269.
47. Price MR, Haase GM, Sartorelli KH, Meagher DP Jr. Recurrent appendicitis after initial conservative management of appendiceal abscess. J Pediatr Surg 1996; 31:291–294.
48. Sivit CJ, Applegate KE. Imaging of acute appendicitis in children. Semin Ultrasound CT MR 2003; 24:74–82.
49. Newman K, Ponsky T, Kittle K, et al. Appendicitis 2000: variability in practice, outcomes, and resource utilization at thirty pediatric hospitals. J Pediatr Surg 2003; 38:372–379.
50. American College of Radiology/Society of Interventional Radiology. ACR-SIR guideline on informed consent for image-guided procedures, Available at http://www.acr.org/~/media/ACR/Documents/PGTS/guidelines/Informed_Consent_Image_Guide.pdf, Accessed June 11, 2012.
51. Malloy PC, Grassi CJ, Kundu S, et al. Consensus Guidelines for periprocedural management of coagulation status and hemostasis risk in percutaneous image-guided intervention. J Vasc Interv Radiol 2009; 20(suppl): S240–S249.
52. Venkatesan AM, Kundu S, Sacks D, et al. Practice guideline for adult antibiotic prophylaxis during vascular and interventional radiology procedures. J Vasc Interv Radiol 2010; 21:1611–1630.
53. Pearce MS, Salotti JA, Little MR, et al. Radiation exposure from CT scans in childhood and subsequent risk of leukaemia and brain tumors: a retrospective cohort study. *The Lancet* June 7, 2012. www.thelancet.com; published online. DOI: 10.1016/S0140-6736(12)60815-0.
54. Govia K, Connolly BL, Thomas KE, Gordon CL. Estimates of effective dose to pediatric patients undergoing enteric and venous access procedures. J Vasc Interv Radiol 2012; 23:443–450.
55. Miller DL, Vano E, Bartal G, et al. Occupational radiation protection in interventional radiology; a joint guideline of the Cardiovascular and Interventional Radiology Society of Europe and the Society of Interventional Radiology. J Vasc Interv Radiol 2010; 21:607–615.
56. Burrows PF, Robertson RL, Barnes PD. Angiography and the evaluation of cerebrovascular disease in childhood. Neuroimaging Clin N Am 1996; 6:561–588.
57. Lock J, Keane J, Perry S. Diagnostic and interventional catheterization in congenital heart disease, second ed. Boston: Kluwer, 2000.
58. Walser E, Raza S, Hernandex A, Ozkan O, Kathuria M, Akinci D. Sonographically guided transgluteal drainage of pelvic abscesses. AJR Am J Roentgenol 2003; 181:498–500.
59. Rao S, Hogan MJ. Trocar transrectal abscess drainage in children: a modified technique. Pediatr Radiol 2009; 39:982–984.
60. Alexander AA, Eschelman DJ, Nazarian LN, Bonn J. Transrectal sonographically guided drainage of deep pelvic abscesses. AJR Am J Roentgenol 1994; 162:1227–1230.
61. Fan WC, Chan CC, Chan JCS. Image guided Drainage Using the Trocar technique. J HK Coll Radiol 2008; 11:69–71.
62. Cheng D, Nagata KT, Yoon HC. Randomized prospective comparison of alteplase versus saline solution for the percutaneous treatment of loculated abdominopelvic abscesses. J Vasc Interv Radiol 2008; 19:906–911.
63. Diamond IR, Wales PW, Connolly B, Gerstle T. Tissue plasminogen activator for the treatment of intraabdominal abscesses in a neonate. J Pediatr Surg 2003; 38:1234–1236.

APPENDIX: CONSENSUS METHODOLOGY

Reported complication-specific rates in some cases reflect the aggregate of major and minor complications. Thresholds are derived from critical evaluation of the literature, evaluation of empirical data from Standards of Practice Committee members' practices, and, when available, the SIR Hi-IQ System national database.