Article published online: 2021-07-22

Basic Interventional Procedures: Practice Essentials

Amar Mukund, Krishna Bhardwaj[1], Chander Mohan[2]

Department of Interventional Radiology, Institute of Liver and Biliary Sciences, D-1, Vasant Kunj, [1]Department of Radiology, VMMC and Safdarjung Hospital, Ansari Nagar, [2]Department of Interventional Radiology, BLK Superspecialty Hospital, Pusa Raod, New Delhi, India

Correspondence: Dr. Amar Mukund, Department of Radiology, Institute of Liver and Biliary Sciences, D-1, Vasant Kunj, New Delhi - 110 070, India. E-mail: dramarmukund@gmail.com

Abstract

There has been an increasing demand in image-guided minimally invasive procedures and these have become an integral part of present-day clinical practice. Basic interventional radiology (IR) procedures have greatly reduced the need for invasive procedures for sampling as well as treating conditions like abscess and fluid collections. Owing to their minimally invasive nature, most of these procedures may be performed on the outpatient patients as daycare procedures. Some of these procedures in critically ill patients may be lifesaving. Basic interventional radiology (IR) procedures consist of image-guided fine-needle aspiration cytology and biopsy, tru-cut (core) biopsy, needle aspiration/drainage and percutaneous catheter drainage. This review aims to provide practice requisites for basic IR procedures.

Key words: Core biopsy; fine-needle aspiration; interventional radiology; per-cutaneous drainage

Introduction

Image-guided minimally invasive diagnostic and therapeutic procedures have become important part of interventional radiology (IR) practice. It has greatly reduced the need for invasive procedures for sampling of deep-seated lesions and treatment of conditions like abscesses and fluid collections. Some of these procedures in may be lifesaving.

The training for these basic IR procedures is not uniform. However, considering the importance of these interventions, it is imperative for all radiologists to have an understanding of these procedures for better patient care. In this review we aim to provide practice essentials for basic IR procedures. These details may be of help for radiologists-in-training as well as radiologists practicing IR.

Access this article online	
Quick Response Code:	Website: www.ijri.org
	DOI: 10.4103/ijri.IJRI_96_19

Basic IR procedures include fine-needle aspiration cytology (FNAC), tru-cut (core) biopsy, needle aspiration/drainage, and percutaneous catheter drainage. IR procedures require knowledge of the hardware, planning, and patient preparation. Hence having a checklist is useful. A sample checklist is provided as Table 1 and hardware list along with representative images is shown in Table 2 and Figures 1 and 2. Details of the procedure, procedural requirement, and post-procedure care are discussed below.

Percutaneous needle biopsy

Percutaneous needle biopsy (PNB) is defined as percutaneous placement of a needle into a suspected lesion [Figure 3] or organ for the purpose of obtaining tissue, cells, or fluid for diagnosis.[1] PNB is one of the most important steps in establishing diagnosis and planning treatment.

Cite this article as: Mukund A, Bhardwaj K, Mohan C. Basic interventional procedures: Practice essentials. Indian J Radiol Imaging 2019;29:182-9.

Table 1: Checklist for basic procedures

Pre procedure check list
Valid referral with procedure name
Patient identification with correct site and side confirmation
Written informed consent
Relevant past medical history/co-morbidity
History of allergy
Review of imaging
Review of medications
Laboratory parameters and coagulation profile
Need for intravenous fluids/blood products
Nil per oral (preoperative fasting) status
Prophylactic antibiotics
Sedation/anaesthesia plan
Radiation safety
Pregnancy status (in females of reproductive age group)
Equipment for physiologic monitoring
Requirement of any special equipment
Specimen to be collected
Any anticipated adverse effect and safety equipment in place

Table 2: Materials and hardware required

FNAC
Local anaesthetic agent
22-25G Lumber Puncture needle (22G/15 cm Chiba in case of deeper Lesions)
Percutaneous biopsy
Local anaesthetic agent
Surgical blade no. 11
Biopsy Gun 14-20G automated or semi-automated
Coaxial Needle (if required)
Gelfoam/embolization coils (In case of plugged biopsy)
Percutaneous catheter drainage
Local anaesthetic agent
Surgical blade no. 11
Trochar technique
Trochar mounted catheter (8 Fr)
Seldinger technique
Introducer needle 18G (should allow 0.035-inch guidewire)
0.035-inch stiff guidewire (90/145 cm)
Fascial Dilators (6-8 Fr up to the required size)
Drainage Catheter (Malecot's or Pigtail as per requirement)
Collection bag (underwater seal bag in case of pleural fluid drainage)
Suture/fixation device
Dressing material

PNB comprises of:

1. Fine-Needle Aspiration cytology (FNAC) using thin needles generally 22G or smaller for aspirating cells for cytological analysis and cell block preparation. Commonly used needles include Chiba and Spinal needles [Figures 1 and 2]
2. Core Biopsy (CB) using needle 20G or larger with cutting mechanism to extract piece of tissue for histo-pathological analysis. Widely used are tru-Cut needles consisting of outer cannula and inner notched trocar with semi-automatic or automatic firing mechanism [Figure 2]. Other types of needles are trephine needles and full core needles.[2]

Co-axial needle system can be used to reduce procedure-related complications when multiple samples are required. Co-axial needle may further be used to embolize

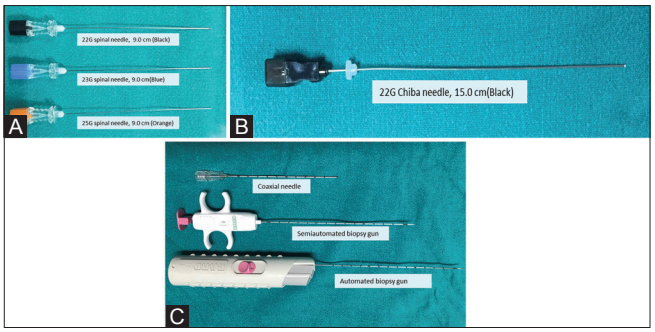

Figure 1 (A-C): Photograph (1A) showing spinal needle of varying caliber commonly used for FNA, (1B) shows a 22G Chiba needle and (1C) shows images of coaxial needle, semiautomated and automated biopsy gun

and plug the needle tract after obtaining the tissue sample in patients at risk of post biopsy bleeding.

Indications

The main indications for image-guided PNB are as:[1-3]

1. To establish the benign or malignant nature of the suspected lesion or tumor
2. To obtain material for microbiologic analysis in patients with suspected infections
3. To document loco-regional spread or distant metastasis in patients with proven or suspected malignancy
4. To determine the primary site of origin in a patient with metastatic disease and an unknown primary
5. To obtain tissue for molecular analysis thus aiding in classification and management of certain malignancies
6. To determine the nature and extent of diffuse parenchymal diseases (liver and renal parenchymal disease, graft rejection).

Contraindications

There are limited contraindications and some of these may be considered relative contraindications:

1. Uncorrectable coagulopathies (procedure can be done after correction with corrected INR to be <1.5 and platelet count to be >50,000/μL)
2. Lack of a safe access to the lesion with interposed vital structures
3. Severe cardiopulmonary disease or hemodynamic instability
4. Inability of the patient to cooperate or patient positioning not possible
5. Pregnancy when imaging modality involves modalities using ionizing radiation like CT or fluoroscopy.

Percutaneous drainage/aspiration

Image-guided percutaneous drainage (PCD) or aspiration has emerged as the treatment of choice for drainage of abnormal fluid collections almost completely replacing surgical interventions. Most procedures in stable patients may be performed as day care procedures. Two types of procedure may be performed depending upon the nature and size of fluid collection:

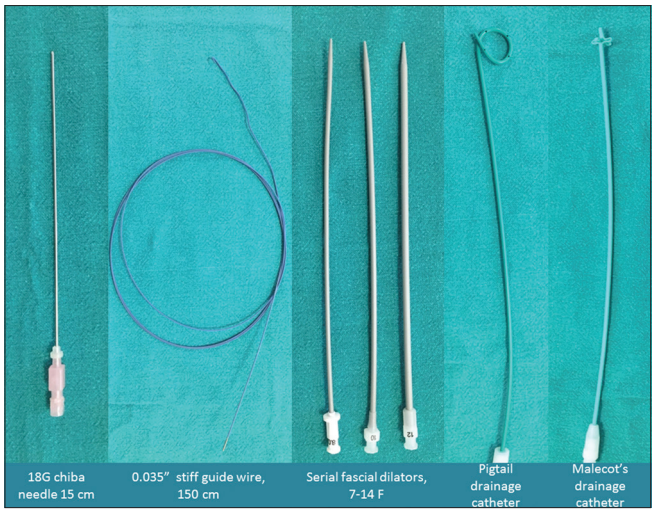

Figure 2: Photograph 2 showing hardware needed for percutaneous drainage using Seldinger technique

1. PCD with indwelling catheter
2. Percutaneous needle aspiration where needle is removed after aspirating the contents.

Catheter insertion for continuous catheter drainage may be performed using two different techniques: Trochar technique and Seldinger technique.

Trocar technique is a simple but relatively traumatic way of inserting a catheter. In this method, a catheter mounted on a trocar is inserted directly under image guidance. It is suitable for large superficial collections and may be performed as a bedside procedure with limited resources. Seldinger technique involves placement of a fine needle into the collection and subsequently advancing a guide wire through the needle. The needle is withdrawn over the guide wire and serial dilation of the tract is performed over the guide wire. Once the tract is adequately dilated, catheter is advanced over the guide wire and finally deployed inside the collection or abscess cavity [Figure 4]. The choice of needle and guide wire depends on the size and location of the collection. For small/critically located collections 21G needle, 0.018-inch guide wire is used and later exchanged with 0.035-inch guide wire using coaxial dilator and sheath system, however for relatively large collections 18G needle with 0.035-inch guide wire may be used.[4] Seldinger technique is less traumatic and poses lesser risk of injury to nearby vessels and other vital structures. However, it is more time consuming and rarely fluid leakage can occur during the manipulation of needle and dilators.

Indications

The main indications for percutaneous drainage/aspiration of fluid collections are:[5,6]

1. To characterize the nature of fluid
2. To confirm the presence of infection
3. To drain abscesses and infected fluid collections in conditions like acute pancreatitis or post-operative status.
4. To relieve symptoms due to sepsis or pressure effect and stabilizing patient before any definitive intervention in complex collections
5. As a part of additional procedure before sclerotherapy in case of recurrent collection.

The contraindications are similar to image-guided PNB.

Pre-procedure requisites

Careful review of pre-procedural imaging and clinical history should be done by the interventional radiologist before planning the procedure. In addition, the indications with intended outcome and risks involved in the procedure should be discussed with referring physician and the patient.

Informed consent should be obtained in all the cases in accordance with local laws preferably by the interventional radiologist performing the procedure. All the benefits and risks should be explained to the patient and/or his attendants in native language.

Laboratory parameters such as platelet count and international normalized ratio (INR) should be evaluated for coagulation status and bleeding risk.[7] Procedures can be classified into low, moderate, and high risk. Antiplatelet medicines or anticoagulants should be discontinued whenever possible particularly in moderate and high-risk patients. Generally, Aspirin and Clopidogrel should be stopped 5 days before any high-risk procedure.[2] Similarly, low molecular weight heparin should be discontinued for one dose to two doses for high-risk procedure.

In general platelet count of more than 50,000 platelets/μL and an INR lower than 1.5 (preferably <1.3) can be used as threshold for most of the cases. All cases of coagulopathy should be corrected using vitamin K injection for planned procedure, and, fresh frozen plasma, platelet concentrates or cryoprecipitate before the procedure or in peri-procedural period depending upon the abnormality in coagulation profile.[7]

Patient preparation

Patient should be fasting (nil per oral) for 8 hours in cases where sedation is required. However, cases of biopsy/superficial drainage can be done with lesser fasting time.

Most of the IR procedures can be performed under local anesthesia with or without conscious sedation. However, general anesthesia may be required for uncooperative patients and children.

Prophylactic use of antibiotics is not routinely recommended except in patients with suspected infection/infected collections.

Intravenous access should be secured in all the patients before the procedure. IR suite should have facility for monitoring vital parameters like heart rate, blood pressure, oxygen saturation, electrocardiogram along with access to emergency drugs and equipment.

Patient positioning

Optimal patient position is one of the key steps for a successful procedure. Depending on the location of the target lesion, short and safe access route, and operator/patient comfort, the patient may be positioned in supine, prone, and various oblique positions. Computed tomography (CT) scanner gantry may be angulated as per the requirement in CT-guided procedures. These simple maneuvers lead to a precise placement of needle/catheter with reduced risk of complication as well as reduced procedure time.

Image guidance

Percutaneous procedures can be done under ultrasound (US), CT, fluoroscopy, MR or positron emission tomography (PET)-CT guidance. The most appropriate modality should be chosen based on factors like site and nature of lesion and adequate visualization of the needle during the procedure.

The route for needle insertion/catheter placement should be the shortest avoiding the vital structures like blood vessels, nerves, bowel, and lung. If transgression of these structures is unavoidable, the smallest possible portion of the tissue should be involved. Certain structures like large bowel and pancreas should be avoided.

US is the simplest and the most commonly used modality for image guidance [Figures 3 and 4]. It has the advantages of wide availability, portability, real time visualization, and lack of exposure to ionizing radiation. However, it fails to provide adequate guidance in obese patients and deep-seated lesions as well as lesions that are obscured by bowel gas.

CT is excellent in providing anatomic detail and precise planning of trajectory and placement of needle. However, it is time consuming and has the disadvantage of exposure to ionizing radiation. CT fluoroscopy can provide real time imaging. CT is the preferred modality for thoracic procedures as well as procedure involving retroperitoneum [Figures 5 and 6].

Fluoroscopy has limited role except in transvenous biopsies and catheter exchange. Radiation dose should be kept to minimum in case of CT and fluoroscopic guidance following ALARA principle.

MRI guidance has limited availability and is used in very few centers due to the cost and the requirement for dedicated MR compatible instruments.

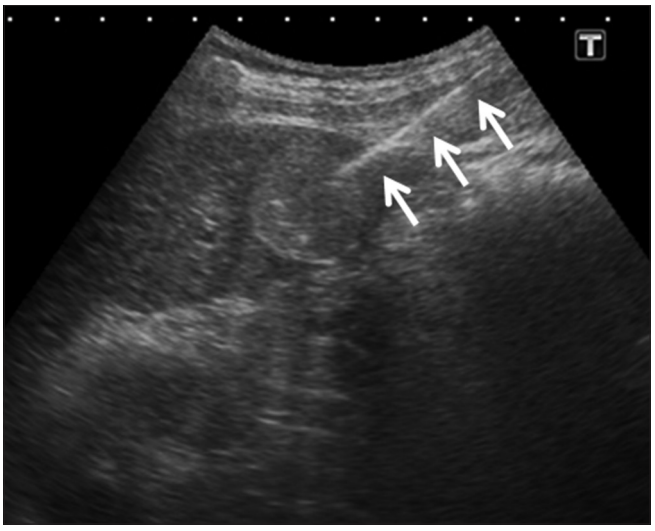

Figure 3: Image showing needle placement for FNA under ultrasound guidance (white arrows)

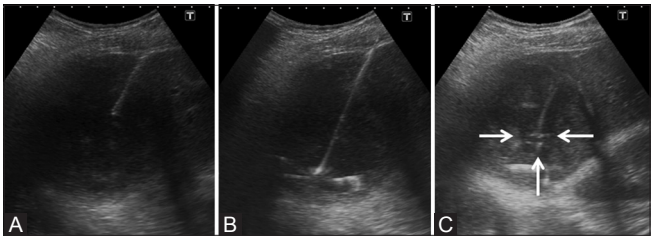

Figure 4 (A-C): Ultrasound image (A) shows initial puncture of the abscess cavity using 18G needle, (B) shows guide wire within the abscess cavity and (C) shows malecots catheter (white arrows) within the abscess cavity

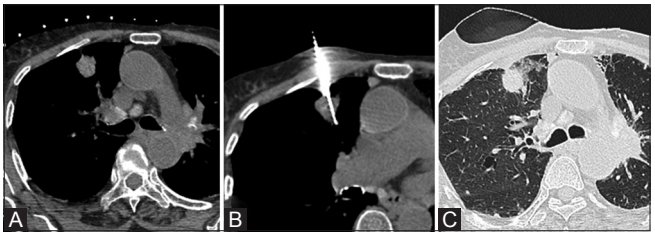

Figure 5 (A-C): CT image in supine position shows (A) markers placed on the anterior chest wall to ascertain the point of entry for biopsy of lung nodule (B) biopsy needle within the lung nodule and (C) post biopsy image with no pneumothorax

Post procedure

After the procedure vitals should be monitored for at least 2–4 hours; every 15 minutes for 1 hour, every 30 minutes for next 1 hour, and hourly thereafter.[8] If vitals are stable, the patient can be discharged with advice for post procedure care and medications (if any). Patient and their attendants should be warned about the signs and symptoms of complications and advised to report immediately in case of any complication.

In case of percutaneous catheter drainage, catheter care is of paramount importance and is best done by interventional radiologist himself. The catheter should be gently flushed

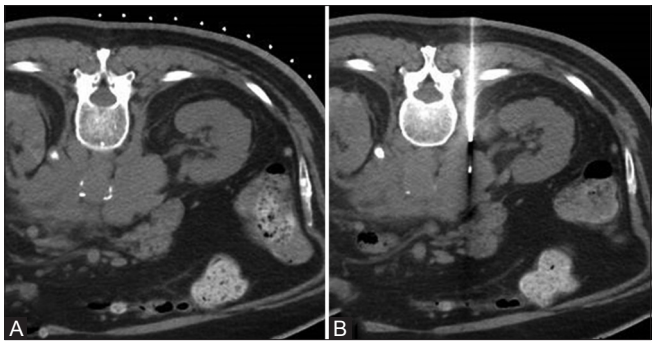

Figure 6 (A and B): CT image in prone position shows (A) markers placed on the posterior abdominal wall to ascertain the point of entry for sampling of retroperitoneal lymph node (RPLN) and (B) the biopsy needle within the RPLN while avoiding all vital structures

every 8–12 hours with 10–15 ml of normal.[4] Persistent high output or any sudden change in the nature of draining fluid warrants a search for the development of fistula. Peri-catheter leak generally suggest blockage or inadequate drainage and requires catheter upsize or exchange. The catheter position should be checked at regular. Catheter removed is done when the output falls to 10–20 ml per day, the vital signs return to normal and no sizable collection is noted.[8]

Complications

The complications of percutaneous procedures can be grouped into procedure-related and organ specific. Additionally, these may also be classified into major and minor according to Society of Interventional Radiology (SIR) guidelines.

The general complications include-

1. Bleeding: Significant hemorrhage is observed in <2% of the cases. However, the risk is relatively increased in case of biopsy of solid organ or hyper-vascular lesions which can be minimized by plugging the tract through co-axial needle with gelfoam/embolization coils[9]
2. Post-procedure infection: it is also very rare and can be further minimized by adhering to strict aseptic and sterile techniques
3. Inadvertent injury to adjacent organs.

The organ specific complications include pneumothorax, peritonitis, pancreatitis, needle tract seeding with tumor cells, etc.

The rates of individual complications published in various studies are highly variable and dependent on referral pattern and patient selection. Interventional radiologist may try to keep the complication to the minimum by following all basic steps. If the rate of complications is higher than the reported threshold, an institutional review should be done to identify causes and rectify them. It is essential to identify complication at its earliest and manage them promptly.

Important medications

Though these basic image-guided interventions are minimally invasive; however, the intervention room should be equipped with crash cart having an inventory of basic drugs including local anesthetics, analgesics, antiemetics, sedatives, and emergency drugs. Common drugs which can be advised and administered by IR include injection lignocaine as local anesthetic agent, injection paracetamol for IV infusion, and injection tramadol/diclofenac as analgesics. Patients may experience nausea and gastritis due to long fasting and stress and may require administration of injection pantoprazole and ondansetron. Sedatives and opioids are to be administered by an anesthetist as they require vitals monitoring.

Special Considerations

Image-guided thoracic FNA and biopsy

Lung lesions mostly require CT guidance for sampling however large subpleural lesions may be targeted using US. The basic principle remains same however some specific points are mentioned below.

For all lung biopsies shortest intercostal route should be taken and fissures, bullous lesions and emphysematous areas should be avoided [Figure 5].[10] It is further imperative to avoid multiple pleural punctures to prevent pneumothorax and for this purpose coaxial devices are useful.[10]

Similarly, sampling of mediastinal lesions also requires CT guidance. Sampling mediastinal masses may be challenging due to limited availability of safe window for the placement of needle. Various approaches are described and include paravertebral, parasternal, and transpulmonary approach.[10]

Despite best efforts, complications may occur. The commonest complication of thoracic IR procedures is pneumothorax. Hence facility for oxygen administration, suction, and chest tube insertion should be available when these procedures are planned.

Image-guided liver and kidney biopsy

Image-guided biopsies are very useful in evaluating diffuse diseases of liver and kidneys.

US-guided parenchymal liver biopsy is considered safer and cost-effective procedure with fewer complications compared to blind procedure.[11,12] Using real time US guidance, sample can be taken using 18G automated biopsy gun from either right or left lobe depending upon institutional or operator preference. Some prefer left lobe subxiphoid approach as it avoids pleural transgression while others prefer right lobe sampling.

Co-axial technique allows post biopsy embolization/plugging of the biopsy tract with gel-foam/coils through the co-axial

needle. Plugged percutaneous biopsy decreases the risk of hemorrhage in high-risk patients.[13]

Similarly, US-guided parenchymal renal biopsy is a useful tool in evaluating diffuse renal parenchymal disease and transplant patient with graft dysfunction.[9] For native kidneys posterior approach is used after positioning the patient in prone or lateral decubitus position.[14] Anterior approach with supine positioning is used in graft kidneys. Lower pole cortex is usually targeted avoiding renal medulla and hilum. It is a relatively safe procedure. Patient should be informed about the possibility of mild transient hematuria. Further evaluation is warranted in case of persistent hematuria.

Hepatic abscess

Image-guided percutaneous needle aspiration or PCD along with antibiotics has become the mainstay of treatment of pyogenic and amoebic liver abscess for patient not responding to medical treatment. Surgical drainage is required a in minority of patients who do not respond to these IR procedures.[15] PCD is more effective than needle aspiration for abscesses larger than 5 cm.[16,17] Using real time USG guidance, needle aspiration can be done using 18G Chiba or Spinal needle. Similarly, PCD can be done using Seldinger technique and 8-12 F drainage catheter can be placed for continuous drainage. It can be done using intercostal or subcostal approach; however, pleural transgression should be avoided.[8] It is advised to have a rim of normal liver parenchyma before puncturing the abscess cavity while avoiding major vessels or dilated biliary radicles.

Pancreatic fluid collections

Morphologically acute pancreatitis (AP) can manifest as self-limiting interstitial edematous pancreatitis (IEP) or more severe life-threatening acute necrotizing pancreatitis (ANP) according to revised Atlanta classification.[18] ANP is associated with a high morbidity and mortality.[18] ANP is subdivided into pancreatic necrosis alone, peripancreatic necrosis alone, and combined pancreatic and peripancreatic necrosis. Associated collections in IEP are referred to as acute peripancreatic fluid collections (APFC) in the initial phase (<4 weeks) and after 4 weeks, these are known as pseudocysts. Similarly, ANP can be associated with acute necrotic collection (ANC) (<4 weeks) and walled off necrosis (WON) beyond 4 weeks.

An integrated multidisciplinary approach involving interventional radiologist, surgeon, and gastroenterologist is often required for management of AP and its complications. IR procedures in the setting of AP consist of needle aspiration and catheter drainage [Figure 7]. Some important points to be considered are-

- Diagnostic needle aspiration is sometimes done for analysis of fluid when there is high degree of suspicion of infection

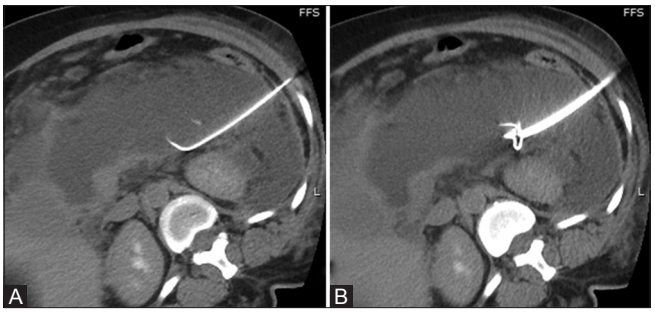

Figure 7 (A and B): CT image in supine oblique position shows (A) a needle with guide wire placed in a large peripancreatic collection using posterior oblique (retroperitoneal approach) avoiding the colon and perirenal fat and (B) needle replaced with a malecots catheter for continuous drainage

- Majority of APFC and pseudocyst resolve spontaneously. Pseudocysts in present era are invariable managed by endoscopic drainage, when they are large (>5 cm) or produce pressure symptoms. However, in situations where endoscopic drainage is not feasible, percutaneous drainage may be considered.[18,19] However, the risk of an external pancreatic fistula is high
- PCD in necrotic collections may be successful alone or as a part of the "step-up" approach.[20] Indications for drainage include suspected infection, persistent or worsening organ failure, intra-abdominal hypertension and persistent sepsis, and should be done after 4 weeks or more after the onset of disease to allow liquefaction and formation of wall around the collection/necrosis.[21] However, in a recent study, it was shown that an early PCD is as effective as a late PCD[22]
- PCD may be performed under US or CT guidance. CT guidance is preferred it allows better visualization of vital structures like bowel, blood vessels, etc., It is also helpful in post procedure assessment and of need for placement of more drainage catheters[23]
- Percutaneous procedures can be done using a peritoneal or retroperitoneal approach. Retroperitoneal approach is favored because it avoids peritoneal contamination and facilitates access for a later percutaneous endoscopic/minimally invasive surgical debridement of a necrotic collection[21]
- A catheter size typically ranges from 12 to 30 F. Frequent irrigation of the collection is done with normal saline to facilitate evacuation of non-liquefied material.[24] Catheters need to be upsized or exchanged in case of catheter blockage/dysfunction.
- Follow-up imaging should be done to assess for resolution of collection or fistula formation with pancreatic duct in case of persistent high drain output
- Stable patients can be discharged with catheter *in situ* after educating them about catheter care. Criteria for catheter removal include no residual collection on imaging and drainage of less than 10 mL per day of non-purulent fluid for two consecutive days.[24]

Percutaneous splenic interventions

Percutaneous interventions in spleen are traditionally avoided due to perceived high risk of complication particularly hemorrhage.[25] However, with growing expertise in IR, image-guided procedures like splenic biopsy, fluid aspiration, and catheter drainage are considered safe and clinically effective.[26]

The main indications for splenic biopsy are to characterize focal splenic lesion and to determine the etiology of splenomegaly of unknown cause.[26]

Splenic abscesses and collections were traditionally managed with antibiotics and splenectomy. However, image-guided treatment is equally effective alternative with high success rate and has the advantage of avoiding long-term immunologic dysfunctions related to splenectomy.[25,26]

CT or US guidance can be used based on pre-procedure imaging evaluation. The access path is planned in a manner to traverse the least amount of splenic parenchyma.[9] Generally subcostal approach is preferred avoiding adjacent structures like colon, kidney, lung, and pleura. Limited pleural transgression can be done in biopsies or FNA if no other approach is feasible.[26]

Pelvic abscess

Deep pelvic abscess may be drained by anterior approach, posterior approach (transgluteal) or endocavitary approach and even by transperineal approach [Figure 8A]. Anterior approach is the simplest to perform but limited window is available for the placement of drainage catheter [Figure 8]. Pelvic abscesses not amenable for anterior approach can be accessed using a transgluteal approach through the greater sciatic foramen.[8,9] CT guidance is used for this approach with patient positioned in prone oblique or lateral decubitus position. The insertion should be as close to the sacrum as possible preferably at infrapiriformis level to avoid neurovascular structures.[27] Transvaginal or transrectal approach is suitable for collections in proximity to the vaginal fornices or to the low rectum. Low collections can be drained via transperineal approach as well.[9]

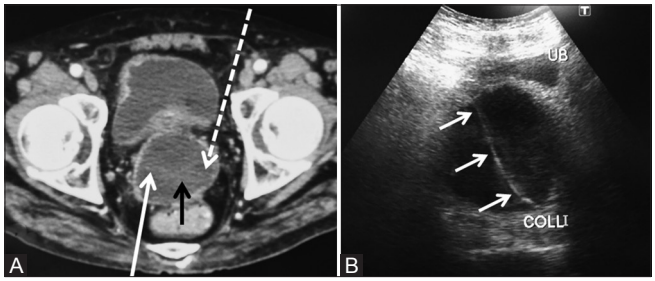

Figure 8 (A and B): CT image (A) shows abscess in the rectovesical pouch (black star) with multiple routes to access and drain the collection. White dotted arrow shows the anterior approach, white solid arrow shows the posterior (transgluteal approach) and black arrow shows transrectal approach (needs endorectal ultrasound guidance). Ultrasound image (B) shows drainage catheter placed in the abscess cavity through anterior paravesical approach (white arrows) after emptying the urinary bladder

Subphrenic abscess

Subphrenic collections and abscesses need special mention due to risk of pleural transgression, which can cause pneumothorax, pleural effusion, or empyema.[28,29] Generally, it is advisable to plan a low subcostal anterior extrapleural access.[9] Sometimes pleural transgression is unavoidable; however, lung transgression should never be done.[28,29]

In conclusion, image-guided minimally invasive nonvascular procedures are one of the most important IR procedures and have become the mainstay in diagnosis and treatment algorithm of modern-day medicine.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

References

1. American College of Radiology. ACR-SIR-SPR Practice parameter for the performance of image-guided percutaneous needle biopsy (PNB) Revised 2018 (Res. 14). Available from: http://www.acr.org/*/media/ACR/Documents/PGTS/guidelines/PNB.pdf.
2. Veltri A, Bargellini I, Giorgi L, Almeida P, Akhan O. CIRSE guidelines on percutaneous needle biopsy (PNB). Cardiovasc Intervent Radiol 2017;40:1501-13.
3. Gupta S, Wallace MJ, Cardella JF, Kundu S, Miller DL, Rose SC; Society of Interventional Radiology Standards of Practice Committee. Quality improvement guidelines for percutaneous needle biopsy. J Vasc Interv Radiol 2010;21:969-75.
4. Gervais D, Brown S, Connolly SA, Brec SL, Harisinghani MG, Mueller PR. Percutaneous imaging-guided abdominal and pelvic abscess drainage in children. Radiographics 2004;24:737-54.
5. Wallace MJ, Chin KW, Fletcher TB, Bakal CW, Cardella JF, Grassi CJ, *et al*. Quality improvement guidelines for percutaneous drainage/aspiration of abscess and fluid collections. J Vasc Interv Radiol 2010;21:431-5.
6. American College of Radiology. ACR-SIR-SPR Practice parameter for specifications and performance of image-guided percutaneous drainage/aspiration of abscesses and fluid collections (PDAFC) Revised 2018 (Res. 13). Available from: https://www.acr.org/-/media/ACR/Files/Practice-Parameters/PDFAC.pdf.
7. Hogan MJ, Marshalleck FE, Sidhu MK, Connolly BL, Towbin RB, Saad WA, *et al*. Quality improvement guidelines for pediatric abscess and fluid drainage. J Vasc Interv Radiol 2012;23:1397-402.
8. Kandarpa K, Machan L. Handbook of Interventional Radiologic Procedures. 5th ed. Philadelphia: Lippincott Williams and Wilkins; 2016.
9. McGrath A, Sabharwal T. Interventional Radiology Procedures in Biopsy and Drainage. Gervais DA, Sabharwal T (ed): Springer, New York; 2011. 10.1007/978-1-84800-899-1.
10. Lal H, Neyaz Z, Nath A, Borah S. CT-guided percutaneous biopsy of intrathoracic lesions. Korean J Radiol 2012;13:210-26.
11. Vijayaraghavan GR, David S, Bermudez-Allende M, Sarwat H. Imaging-guided parenchymal liver biopsy: How we do it. J Clin Imaging Sci 2010;1:30.

12. Farrell RJ, Smiddy PF, Pilkington RM, Tobin AA, Mooney EE, Temperley IJ, *et al*. Guided versus blind liver biopsy for chronic hepatitis C: Clinical benefits and costs. J Hepatol 1999;30:580-7.
13. Tsang WK, Luk WH, Lo A. Ultrasound-guided plugged percutaneous biopsy of solid organs in patients with bleeding tendencies. Hong Kong Med J 2014;20:107-12.
14. Uppot RN, Harisinghani MG, Gervais DA. Imaging-guided percutaneous renal biopsy: Rationale and approach. AJR Am J Roentgenol 2010;194:1443-9.
15. Cai YL, Xiong XZ, Lu J, Cheng Y, Yang C, Lin YX, *et al*. Percutaneous needle aspiration versus catheter drainage in the management of liver abscess: A systematic review and meta-analysis. HPB (Oxford) 2015;17:195-201.
16. 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;170:1035-9.
17. Zerem E, Hadzic A. Sonographically guided percutaneous catheter drainage versus needle aspiration in the management of pyogenic liver abscess. AJR Am J Roentgenol 2007;189:W138-42.
18. Thoeni RF. The revised Atlanta classification of acute pancreatitis: Its importance for the radiologist and its effect on treatment. Radiology 2012;262:751-64.
19. Maher MM, Lucey BC, Gervais DA, Mueller PR. Acute pancreatitis: The role of imaging and interventional radiology. Cardiovasc Intervent Radiol 2004;27:208-25.
20. van Santvoort HC, Besselink MG, Bakker OJ, Hofker HS, Boermeester MA, Dejong CH, *et al*. A step-up approach or open necrosectomy for necrotizing pancreatitis. N Engl J Med 2010;362:1491-502.
21. Freeman ML, Werner J, van Santvoort HC, Baron TH, Besselink MG, Windsor JA, *et al*. Interventions for necrotizing pancreatitis: Summary of a multidisciplinary consensus conference. Pancreas 2012;41:1176-94.
22. Mallick B, Dhaka N, Gupta P, Gulati A, Malik S, Sinha SK, *et al*. An audit of percutaneous drainage for acute necrotic collections and walled off necrosis in patients with acute pancreatitis. Pancreatology 2018;18:727-33.
23. Shyu JY, Sainani NI, Sahni VA, Chick JF, Chauhan NR, Conwell DL, *et al*. Necrotizing pancreatitis: Diagnosis, imaging, and intervention. Radiographics 2014;34:1218-39.
24. Segal D, Mortele KJ, Banks PA, Silverman SG. Acute necrotizing pancreatitis: Role of CT-guided percutaneous catheter drainage. Abdom Imaging 2007;32:351-61.
25. Singh AK, Shankar S, Gervais DA, Hahn PF, Mueller PR. Image guided percutaneous splenic interventions. Radiographics 2012;32:523-34.
26. Sammon J, Twomey M, Crush L, Maher MM, O'Connor OJ. Image-guided percutaneous splenic biopsy and drainage. Semin Intervent Radiol 2012;29:301-10.
27. Harisinghani M, Gervais D, Hahn P, Cho CH, Jhaveri K, Varghese J, *et al*. CT-guided transgluteal drainage of deep pelvic abscesses: Indications, technique, procedure-related complications, and clinical outcome. Radiographics 2002;22:1353-67.
28. Maher MM, Gervais DA, Kalra MK, Lucey B, Sahani DV, Arellano R, *et al*. The inaccessible or undrainable abscess: How to drain it. Radiographics 2004;24:717-35.
29. McNicholas MM, Mueller PR, Lee MJ, Echeverri J, Gazelle GS, Boland GW, *et al*. Percutaneous drainage of subphrenic fluid collections that occur after splenectomy: Efficacy and safety of transpleural versus extrapleural approach. AJR Am J Roentgenol 1995;165:355-9.