Image guided percutaneous biopsy has become the initial procedure of choice in most cases for obtaining bone samples for histological and microbiological assessment. It is a minimally invasive procedure which offers multiple advantages over open surgical biopsy including maintenance of bone structure, minimal soft tissue injury, reduced need of general anesthesia, reduced hospital stay and a low rate of post-procedure complications. In some cases, it can be combined with therapeutic procedures such as cementoplasty and cryoablation via the same access route. For the radiologist, knowledge of the key principles is essential for a safe and effective procedure, particularly when a sarcoma of bone is in the differential diagnosis. In this article we cover the core concepts of percutaneous bone biopsy including indications and contraindications, essential planning steps, appropriate imaging modalities, equipment selection, common approaches, technique as well as avoiding, recognizing and treating complications. Recent technological advancements in this field are also discussed.

**Keywords** Bone biopsy, percutaneous, CT guided, Real time fluoroscopy, Experguide

**Introduction**

Percutaneous bone biopsy (PCBB) has become the initial procedure of choice over open surgical biopsy for most cases to establish a histopathological or bacteriological diagnosis. It is a minimally invasive technique that offers multiple advantages, including maintenance of bone structure, minimal soft tissue injury, avoidance of general anesthesia, reduced hospital stay, lower cost, and lower rates of post-procedure complications.1

Percutaneous biopsy for diagnosis of skeletal lesions was first described by Coley et al in 19311 and Lalli was the first to describe fluoroscopy-guided aspiration biopsy of skeletal lesions in 1970.2 Since then, there have been multiple groundbreaking developments in imaging modalities and equipment such as needles and drills. Recently, there have been significant advancements, including fusion imaging, real-time 3D needle guidance, and the introduction of robotics.

This article discusses the basic concepts of bone biopsy, including; indications and contraindications, common approaches, equipment and imaging modalities, complications, and recent advancements.

**Indications**

The decision to biopsy and interpretation of the result should always be taken in the context of the clinical, laboratory, and diagnostic imaging findings. Some lesions have characteristic and benign appearances, which may negate the need for histology. Appropriate clinical specialist review and full imaging workup should precede biopsy as subsequent imaging findings may be confounded by post biopsy changes. A list of indications is found in Figure 1.
**Contraindications**
Infection in the biopsy route for uninfected bone should be considered an absolute contraindication. There are other relative contraindications, risks and benefits for individual cases should be considered. For hemostatic concerns we recommended reference to the latest SIR guidelines. A list of contraindications is listed in Figure 2.

**Image guidance**
Various imaging modalities can be used for guidance of percutaneous bone biopsy. CT is most commonly used; however the applications, advantages, and disadvantages of each modality are discussed below.

**Ultrasound**
While unable to penetrate the cortex to visualize lesions within a bone, ultrasound can be used when a sizable soft tissue component has breached the overlying cortex. In this scenario, real-time imaging of needle advancement in different planes is advantageous, especially for obtaining multiple cores. Additional advantages include:
- The absence of ionizing radiation.
- The utility of color Doppler to identify highly vascular or necrotic/cystic areas of the lesion to avoid.
- Visualization of adjacent neurovascular bundles.

**Fluoroscopy**
Fluoroscopy is most commonly used for long bone biopsies and should ideally be biplanar. It may offer more flexibility and comfort regarding patient positioning compared to CT and MRI. Needle movements can be visualized in real-time, and motion artifact is less marked. This equipment is often more readily available. Fluoroscopy, however, typically offers poorer visualization of both the lesion and vulnerable adjacent soft tissue structures when compared to CT, by which it has been largely superseded.

**Advanced real-time 3D fluoroscopy guidance using Cone Beam CT**
Combination cone-beam CT and fluoroscopy units offer the advantages of both 3-dimensional and real-time imaging.
Following an initial CT, a needle track can be planned in 3 planes, and then the needle is advanced along the route under real-time fluoroscopy with a high degree of accuracy.

In our institution XperGuide planning software (Philips Healthcare) is used in combination with a biplane fluoroscopy unit with cone beam CT from the same provider. This modality is typically only used in our institution when a biopsy is being performed in addition to bone cement augmentation and thermoablation (Fig. 3). 

Braack et al. reported a 100% technical success rate in needle placement, within 5 mm safety margin, in 145 interventional procedures using this technology.3

In another study comparing accuracy of cone beam CT and conventional CT, Tselikas et al. found that cone beam CT with real time 3D navigation has similar sensitivity for obtaining diagnostic samples while being significantly more accurate (3 mm Vs 5 mm) and imparting a lower radiation dose.4

CT

Due to the fine bone detail combined with good basic overlying soft tissue evaluation and availability, CT remains the preferred method for bone biopsy in most cases. This allows most osseous lesions to be well visualized while avoiding delicate adjacent soft tissue structures. An up-to-date planning scan can be initially performed, followed by a series of short-range scan passes for each needle repositioning, 

Hemostatic abnormalities

- INR>1.5-1.8.
- Low platelets count (<50000). Consider platelet transfusion.

Infection

Infected soft tissues surrounding the bone to prevent the spread of infection to otherwise non-infected bone; this includes infection of overlying skin rendering the lesion inaccessible.

Pregnancy

Creates challenges regarding both the use of ionizing radiation and medication for sedation. A multidisciplinary team discussion of the case to consider the risks and benefits of post-partum procedural delay is advised.

Unstable / non-cooperative patient

Highly vascular tumors

Especially within vulnerable locations where bleeding may be difficult to control or particularly harmful such as the spine. Consider pre-embolization.
initiated from inside or outside the scanning room, with respective time or radiation saving for the operator. The higher radiation dose for the patient and potentially the operator is a disadvantage of CT guidance when compared to other modalities, in addition to the potential loss of real-time viewing of needle movement, depending on available equipment. In a study conducted by Monfardini et al. on cancer patients with suspected bone metastases, CT guided percutaneous biopsy obtained an adequate sample for histopathological diagnosis in 94.1% of 308 biopsies.5

PET/CT

PET/CT is a hybrid imaging modality utilizing integrated CT and PET scanners to demonstrate abnormal metabolic activity in tissue combined with anatomical cross-sectional imaging. Fluorine 18 (F18) fluorodeoxyglucose (FDG) is the most common radiotracer used in PET/CT.6 This has utility in the detection and characterization of osseous lesions, biopsy planning and in some cases, implementation.

The main advantages of utilizing PET/CT include:

- Early diagnosis and staging: PET/CT can demonstrate anatomically occult lesions by demonstrating increased metabolic activity.6
- Increased diagnostic yield: This modality can demonstrate viable tissue in tumors with necrosis or inhomogeneous FDG uptake.6
- It can demonstrate viable/recurrent metabolically active tissue at the sites where anatomic alteration by prior surgery or radiotherapy makes diagnosis difficult.6 (Fig. 4).
- In the case of multiple lesions, the most metabolically active lesion can be targeted.6

Wang et al. reported an overall success rate of 84% bone biopsy based on PET/CT in patients with primary lymphoma.7 Guo et al. reported a 100% overall diagnostic success rate and sensitivity of PET/CT guided percutaneous bone biopsy in lung cancer and suspected metastatic osseous disease.8 However, one must bear in mind the possibility of false positive or non-malignant FDG uptake and artifacts.8 When in doubt, consultation with a nuclear medicine specialist is advised.

Needle placement optimization using PET/CT

Although hypermetabolic lesions visualized on PET/CT can be targeted with conventional CT alone, this can be difficult when the lesion is both occult and small. Correlation using anatomical landmarks may overcome this problem. The diagnostic yield can also be improved by utilizing one of the following advancements:

- Use of limited / one-table-position PET/CT can confirm needle placement within the hypermetabolic region of interest.6
- Fusion imaging utilizing image data from intraprocedural CT and prior PET/CT can be utilized for confirmation of correct needle placement.6
- Real-time PET/CT guidance utilizing electromagnetic needle tracking and navigation system. A weak electromagnetic field and positioning sensor on the needle provides real-time tracking of the position and orientation of the biopsy needle under ultrasound or CT guidance. The software also has the capability of fusing needle position with prior cross-sectional imaging.6

Automated robotic arm-assisted real-time PET/CT guided needle navigation for percutaneous bone biopsy is a new and highly accurate technology with submillimeter accuracy in targeting lesions. Kumar et al. reported 98.6% diagnostic yield, sensitivity 98.2%, and 100% specificity utilizing this recent innovation.9

MRI

MRI guidance can be utilized when radiation avoidance is most desirable, eg, in pregnant patients to avoid fetal...
radiation exposure. It also offers better visualization of soft tissues and delineation of bone lesions not visualized on other modalities.²

Technical difficulties such as MR compatibility of materials being used, lack of scanner availability, positioning difficulties, claustrophobia, non-MRI compatible internal patient devices, and cost limit the routine use of MRI in PCBB.²

**Procedure**

**Pre-procedure preparation (Clinical, Biochemical and Imaging review)**

All biopsy routes for potential sarcoma should be planned in advance with an orthopedic oncology surgeon. Prior imaging is reviewed to confirm lesion location and establish adjacent vulnerable structures and compartmental anatomy. Confirm with the pathologist of what sample pots, core gauge, numbers, and types are required or preferred.

A 6-hour preprocedural NPO is recommended along with any necessary cessation of anticoagulants as per Society of Interventional Radiology guidelines.¹⁰ Patient records are also checked to confirm the correct biopsy site and, in addition to history and physical examination, identify contraindications such as coagulopathy, local infection and establish drug allergies. Conditions that may impact patient positioning, such as impaired mobility and deformity, can be established at this time.

Informed consent is obtained from the patient to cover potential common and serious complications.

**Materials**

A list of required equipment can be found in Figure 5.

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**Medications**

**Local anesthesia**

One percent lidocaine hydrochloride is the most commonly used local anesthetic agent for these procedures.¹ Patient's skin, subcutaneous layers, muscles, and periosteum is infiltrated with the local anesthetic is using a 22-gauge needle to ensure sufficient pain management.¹ Longer acting local anesthetics such as ropivacaine or bupivacaine may be used to prolong working time if required.¹

**Sedation**

Conscious sedation can be considered depending on patient anxiety and likely degree of procedural pain. Midazolam and fentanyl are common agents. This should be administered by a trained separate non-scrubbed operator such as a nurse or anesthesiologist.

More advanced/General anesthesia may be required for children, noncooperative patients, complex or especially painful procedures such as sampling suspected osteoid osteomas. An anesthesiologist should be involved in such cases.¹

**Biopsy needle selection**

The type of needles used can be categorized into three main subtypes, each having a specific application.²

**Fine aspiration needles**

These are used for simple aspiration and cytology and present a lower hemorrhagic risk. Their role in bone biopsy is, however, limited. Soft tissue lesions of bone breaching the cortex in relatively superficial locations and coexisting fluid can be sampled for culture and cytology, which may suffice for some infection and metastatic disease cases. However, the resulting sample has limited potential for histological analysis and is usually unsuitable for soft tissue sarcoma.

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Figure 5  Recommended equipment for bone biopsy.

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Sterile drapes and gauze.
Sterile gloves
Topical skin disinfectant
Syringes
1% lidocaine for local anesthesia (can be combined with bupivacaine as a 50-50% mix)
Lead apron (if required).
Spinal needle (22G)
Selected biopsy system and drill
Surgical scalpel
Orthopedic hammer
Saline
Sample pots
Emergency treatment trolley
Soft tissue core biopsy needles
These can be used to biopsy soft tissue components of bone lesions where the bone cortex has been breached by tumor or by a bone biopsy needle. Such needles are typically primed then 'fire' an outer cannula over an inner collection tray placed into the lesion (Figure 6). A coaxial system can be used to avoid contaminating the biopsy track.

Bone biopsy needles
Different systems are available on the market. In general, these systems are typically coaxial and comprise an introducer, like a vertebroplasty needle, with a diamond or beveled tipped central stylet and outer cannula (Figure 6). This can be advanced into the bone using hand or power drilling or an orthopedic hammer. Once the needle is positioned at or within the lesion, the solid central stylet can be removed and replaced by a saw-toothed biopsy trocar, for collecting the sample by hand or power drilling.

Consideration can be given to using a combination of needles, for example, passage of a soft tissue biopsy or fine needle through a bone biopsy cannula into a soft tissue lesion encased in bone. Aspiration can also be performed via a bone biopsy cannula for culture and cytology (Fig. 7).

Patient and equipment positioning
The patient is positioned in a way that offers direct access to the planned needle route and is comfortable for both the patient and the operator. The positioning can be facilitated with the use of pillows, bolsters, and other support devices.

Figure 6 Different Biopsy Needles: (A) Fine aspiration needle (N) and Stylet (S) (B) Core Biopsy Needle. Inset, close up of cutting mechanism. (C) Bone biopsy Needle. (O) Obturator (S) beveled tipped stylet (T) outer trephine cannula. Inset, close up of trephine tip. (D) Drill and sterile cover. (Color version of figure is available online.)

Figure 7 Infective sacroiliitis with osteomyelitis. Fluid aspiration and bone biopsy. (A) Axial planning CT demonstrates a lytic/sclerotic destructive process in the right sacroiliac joint extending into the adjacent sacrum and ilium. A wire marker is in situ for entry point planning (arrow). (B) A fine needle was used to aspirate fluid for culture and cytology. (C) Subsequent bone biopsy was performed using a bone biopsy set.
The CT gantry diameter must be accounted for when using long biopsy needles. It can be overlooked and lead to needle striking against the gantry and being displaced once the table is moved for scanning.

If general anesthesia is used, care must be given to safe patient position to prevent iatrogenic neuropraxia. The ulnar nerve is the most commonly injured nerve due to patient mispositioning during general anesthesia. It is followed by brachial plexus injury, seen in 0.2% of patients undergoing general anesthesia. The position of anesthetic leads and tubing must also be accounted for and secured.

Depending on the scanner, physical or virtual gantry tilt may be available to allow cranial or caudal angulation of the visualized access route. This allows for better avoidance of a vulnerable structure such as neurovascular bundle or better lesion access with a longer intralesional track for a larger sample.

**Biopsy approach**

**Important consideration for suspected sarcoma**

When planning a percutaneous bone biopsy, special care is required when a primary bone sarcoma is suspected, and curative lesion resection is planned. Tumor seeding and recurrence in the biopsy tract is a potential risk of PCBB thus, surgeons excise the biopsy track at the time of surgery.

The biopsy route should be planned with a sarcoma surgeon to ensure that the biopsy does not contaminate uninvolved compartments or otherwise adversely affect curative and reconstructive potential. Failure to do so risks unnecessary amputation, a larger radiotherapy field, and higher rates of disease recurrence.

A multicenter study involving 596 cases conducted by Musculoskeletal Tumor Society (1996) found that inappropriately performed biopsies led to unnecessary amputation in 5%-8% of the cases.

**Common Biopsy approaches**

As discussed, each sarcoma biopsy case requires prior specialist surgical advice and approval. This will often involve one of the shortest routes avoiding multiple/unaffected compartments. The following considerations may be helpful in planning, but should not replace or supersede surgical instruction.

- Peripheral bones: Orthogonal approach to the bone cortex can help avoid needle slippage. Avoid uncleaned muscle compartments and neurovascular bundles.
- Flat bones (eg, ribs, sternum, and skull): Approach with the angle of 30°-60° to the surface and opposite in direction to the curvature of the bone allows access with reduced risk to underlying structures. The use of a beveled tip needle may offer a better surface grip than a diamond tip in these cases.
- Bony Pelvis: Generally favors intramuscosous routes avoiding uncleaned muscle compartments and neural foramina.
- Vertebral bodies: The approach varies depending on the location of the lesion; however, lesions in the vertebral body are generally accessed via a transpedicular approach.
- Shoulder: Anterior deltoïd approach may be favored as resection of posterior deltoïd results in a denervated anterior deltoïd. Also, the deltopectoral groove and pectoralis muscles should be avoided as the pectoral muscles are utilized in reconstructive surgery.
- Humerus: Anterolateral approach may be appropriate to avoid nerve damage. Beware of the spiral course of the radial nerve, however.
- Femur: Biopsy route should spare the rectus and quadriceps muscles are essential for functional limb sparing surgery. For the proximal femur, posterolateral approach through vastus lateralis may be desired. Alternatively medial approach is possible through the adductor longus. In the distal femur an approach through vastus medialis may be desired. Alternatively, a lateral approach through the vastus lateralis.
- Tibia: Anteromedial cortical approach may be preferred as there is very little overlying functional soft tissue.

**Procedural steps**

- After obtaining informed consent, the patient is positioned on the table to allow best access and ensure patient and operator comfort.
- An IV line is maintained. ECG monitor and a pulse oximeter is attached for monitoring. The patient's vitals are recorded before the procedure as well as every 15 minutes during the procedure. If indicated IV fluid or blood product infusion may be administered.
- IV sedative is administered, usually midazolam and/or fentanyl.
- The site is marked and then cleansed with antiseptic solution and drapes are applied. Be aware that needles/blades passing through marking ink may generate a small tattoo.
- Using a 22-25 G needle for local anesthesia to the skin, subcutaneous soft tissues, muscles and periosteum.
- A small skin incision (0.5-1 cm) is made and the biopsy introducer is advanced in preplanned trajectory under imaging guidance till the bone surface is reached. For sarcoma cases, the incision should ideally generate a small scar that will guide the orthopedic surgeon’s biopsy track excision.
- A surgical hammer or drill allows the introducer to breach the osseous cortex and advance the needle to the lesion. The outer sheath tip must be placed in a stable position within or through the cortex to prevent movement and loss of access. The needle should not be advanced into the lesion area for biopsy with stylet in situ otherwise a hollow track may be created which will impair tissue collection by the hollow biopsy needle.
- The inner stylet of the introducer is removed, and the biopsy trochar is advanced into the lesion via hand or power drilling (Figs. 8 and 9). This is usually passed beyond the cannula tip over the desired length of the
sample core. Power drilling is often necessary for sclerotic lesions, but care should be taken to advance slowly and intermittently to avoid overheating and resulting needle tip shear. Ideally, three cores should be obtained.

The biopsy specimen is assessed for adequacy and fixed in 10% formalin and sent for histopathology. If a bacteriological analysis is requested, then the sample is typically placed in saline and sent for culture. Samples for lymphoma and genetics may have special requirements, always confirm with the pathologist. The biopsy needle should be cleansed in saline before each return pass into the patient to avoid contamination of the biopsy site with toxic formalin.

At this point, if desired, any additional procedure such as cryoablation or cementoplasty can be carried out using the same sheath. (Fig. 10)

Remove the sheath. Ensuring adequate hemostasis by applying local pressure and apply an adhesive bandage to the puncture site.

Patient is monitored till the effects of IV sedative wanes. The biopsy site is monitored every 15 min during the first hour and hourly afterward.

A stitch can be placed at the biopsy site to ensure easy detection by surgeon time of surgery (discuss their preference with the surgeon pre-procedure) so that, it is easier to identify and resect the whole biopsy track.

Avoiding, recognizing, and treating complications

Complications of bone biopsy are rare, with an overall incidence of 0.52%. These include:

- Anaphylactic reactions to medications. An emergency equipment trolley including Epinephrine, antihistamine, corticosteroid and IV fluids should be easily accessible.
- Vasovagal reaction is usually avoided by having the patient recumbent for the procedure.
- Hardware failure/needle fracture with retained fragments: Exercise caution and intermittent biopsy needle advancement, especially when using the drill in sclerotic bone. Should this occur, surgical consults and covering antibiotics may be required. Needles that become stuck within the bone should have the stylet replaced to reinforce the cannula and may be removed.
with an orthopedic torque device. Gentle intermittent rotation of the introducer during advancement can ensure the needle can be rotated and, thus, can be removed. Do not further advance the needle if significant bending is seen.

- **Bleeding:** Active bleeding from a highly vascular tumor or injury to a large vessel may lead to hypovolemic shock, though such severe bleeding/injury is rare under image guidance. Pre-embolization can be considered for high-risk cases. Localized hematomas can usually be managed with 5-10 minutes of local manual pressure followed by a pressure dressing. Use of hemostatic materials via the cannula could be considered. Severe cases necessitate resuscitation and surgical consult.

- **Infections:** Soft tissue, bone, joint and epidural infections can occur. However, the incidence is low, particularly compared to open surgical biopsies. The risk of infections at time of consent and seek prompt medical attention if required.

- **Neurological complications:** Peripheral nerve injury can occur during needle placement. Avoid yawing motions of the needle tip within the soft tissue during placement, which increases the risk of neurovascular injury; retract, angle correct, and advance instead. An intraspinal hematoma may cause spinal cord compression, suspicion for which should prompt emergent MRI and surgical consult.

- **Pneumothorax or hemothorax** may result from thoracic biopsies. Small pneumothorax can be observed and followed radiographically. Larger volumes require chest tubes and admission.

- **Injury to other adjacent soft tissues/organs** Reflex sympathetic dystrophy (very rare).

- **Tumor dissemination** in the biopsy track. Advise coaxial system use and prior surgical planning.

### Conclusion

Image guided percutaneous bone biopsy is a safe and effective method for tissue samples for histological and bacteriological assessment. Careful planning with the surgical team and pathologist is key. While many fundamental principles have remained constant, advances in clinical knowledge, imaging modalities, and interventional innovations continue to improve the safety and scope of these procedures.

### References


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**Figure 10** Fluoroscopy guided vertebral biopsy and cementoplasty. (A) Lateral fluoroscopic view demonstrates a wedge compression of the L1 vertebra. A vertebroplasty needle has been advanced in the posterior vertebral body (arrow). (B) A trephine biopsy needle was then advanced through the same cannula beyond the tip and a biopsy was obtained to confirm or exclude a malignant cause for the vertebral collapse (arrow). (C) The biopsy needle was then withdrawn and cementoplasty was performed via the same cannula.