Percutaneous CT-Guided Vertebral Biopsy: Anatomy and Technical Considerations

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Abstract

In this review article, the authors discuss the anatomy and technical aspects of CT-guided biopsy of vertebral lesions. CT guidance is highly useful for vertebral biopsies, as the anatomy of the spine is complex and varies widely across the levels. Prebiopsy imaging should be reviewed and later correlated with the final histopathological diagnosis. The majority of the spine biopsies are performed under local anesthesia, except those in critical locations and pediatric age groups. The biopsy sample is sent for histopathological analysis and/or microbiological analysis depending on the indications. It is preferable to use a coaxial system for biopsies, so multiple cores can be obtained with a single needle puncture, thus minimizing the negative yield and complications. Complications after image-guided percutaneous biopsy are rare and can be managed easily.

Keywords

- spine biopsy
- percutaneous biopsy
- vertebral lesions

Spinal pathologies pose a major diagnostic challenge on the plain radiographs; however with the advent of cross-sectional imaging like CT, PET-CT and MRI, the diagnostic dilemma have reduced to a large extent and these modern radiological imaging tests have a good predictive value.¹²³ The vertebral column is affected by a variety of disease processes ranging from benign (“touch-me-not”) lesions to infective and aggressive neoplastic lesions, which require histopathological diagnosis to initiate appropriate treatment.⁴ Biopsies can be performed either by open or percutaneous image guidance. Percutaneous needle biopsy under image guidance is safe and less invasive and can be performed as a day-care or outpatient procedure. It has also lower morbidity and cost as compared with open biopsy.⁵⁶⁹ Open biopsies are reserved when a percutaneous biopsy is indeterminate on repeated occasions, and there is a high suspicion of malignancy on imaging. Vertebral anatomy is variable at different spinal levels and understanding the anatomical differences can guide the operator on the safe path for biopsy. This review focuses on the relevant anatomy of the spine at various levels, technical aspects of targeting the lesion, and the advantages and limitations of each approach based on the location of the target lesion. Other topics discussed include are patient preparation, image guidance, lesion localization, biopsy techniques, needle selection, and methods to minimize complications.

Normal Spinal Anatomy

The spinal column consists of 33 vertebrae, which are grouped into different regions as cervical (7 vertebrae), thoracic/dorsal (12 vertebrae), lumbar (5 vertebrae), sacral (5 vertebrae), and coccyx (4 vertebrae). The cross-sectional anatomy of the spine (→Fig. 1) is important to know, as it guides the biopsy approach to avoid injury to vital neurovascular structures. Vertebral consists of anterior arch elements and posterior arch elements. Anterior arch structures consist

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of the vertebral body and anterior ⅜rd of the pedicles, while posterior arch structures consist of posterior ⅜rd of the pedicles, lamina and transverse and spinous processes. The spinal cord is within the spinal canal and is segmented by the nerve roots that emerge from it. There are 31 nerve roots in total eight cervical, 12 thoracic, five lumbar, five sacral, and one coccygeal.10,11

Anatomical variations exist in the pre and paravertebral spaces at different levels, and it is important to know their boundaries and identify complications such as hematoma. The paravertebral space surrounds the vertebral column and extends from the skull base to the mediastinum in the cervical region. This space is encircled by the deep layer of the deep cervical fascia, which divides the paravertebral space into an anterior prevertebral space and posterior paraspinal space. The prevertebral space extends from the skull base to the coccyx.12 In the dorsal region, the paraspinal space gives spinal roots from the intervertebral foramen and divides into dorsal and ventral rami. The sympathetic chain lies in the same fascial plane, just anterior to the intercostal nerve. In the lumbar region, the paravertebral space is limited by the psoas major muscle anterolaterally; the vertebral bodies, the intervertebral discs, and the intervertebral foramen with its contents medially, and the transverse process and the ligaments that are interposed between the adjoining transverse processes posteriorly. Knowledge of this anatomy is important while doing the spine biopsy.

**Procedure**

**General Principles and Procedural Details**

Before performing the biopsy, procedure preplanning and workup are essential to avoid untoward complications and have a safe procedure.

1. **Patient assessment**

   Before performing the biopsy, a thorough clinical evaluation should be performed. Specific attention should be paid toward medical history, prior spinal surgery/instrumentation, spinal trauma, comorbidities, medications, allergies, physical examination findings, and performance status of the patient. One should be aware of the indications and contraindications for the biopsy. The common indications for spinal biopsy include:
   - To differentiate between a benign and malignant lesion.
   - To determine the nature of a solitary bone lesion with nonspecific findings.
   - To evaluate tumor recurrence following surgical or percutaneous therapy.
   - Obtain material for culture and sensitivity in case of suspected infections.

   The **contraindications** include:
   - Uncorrectable coagulopathy.
   - Vascular lesions in the spine.
   - Lack of safe access, that is, risk of injury to neurovascular structures.

   The laboratory tests for hemoglobin, platelets, and coagulation profile should be obtained. The minimum level of hemoglobin level should be more than 8.0 g%, platelet counts more than 50,000 per microliter (ml), and international normalized ratio (INR) less than 1.5. The deranged coagulation profile should be corrected before the procedure to avoid potential bleeding complications.13 According to the CIRSE14 and SIR guidelines,15 spine biopsy falls into category two, that is, a moderate risk procedure. According to these guidelines, warfarin and clopidogrel should be stopped 5 days prior to the procedure, but acetylsalicylic acid (aspirin) may be continued. Low-molecular weight heparin (LMWH) should be withheld for one dose prior to the procedure. However, the newer direct oral anticoagulant (DOAC) should be withheld 2 to 3 days prior to the procedure.16 If INR is elevated, vitamin K injection should be considered at 10 to 20 mg/day for 3 days via intravenous, subcutaneously, or intramuscular routes. Platelets should be infused if the manual count is less than 50,000/mL prior to the procedure. Written informed consent is taken after explaining the risks and benefits of the procedure.

2. **Biopsy planning**

   All available imaging should be reviewed prior to the procedure to decide patient position and biopsy approach. Usually, lesions in the thoracic or lumbar spine are approached in a prone position. If the patient cannot lie in a prone position, a lateral decubitus position may be used. The supine position is preferred for cervical vertebral body biopsy. Tilting the head away from the side of the target lesion is useful, especially for cervical body lesions. For lesions in the posterior elements of the cervical spine, biopsy should be done from a prone or lateral approach. Sometimes, the lesion may be well-visualized on MRI or PET-CT very easily but not on the CT, which is obtained during the biopsy. Therefore, an approximate correlation based on anatomic landmarks or image fusion with the use of dedicated software should be performed to determine the location of the lesion. Prebiopsy CT, MR, or PET images are also useful to target the most representative right area of the lesion such as the non-necrotic area or the solid component at the lesion periphery.1

   Limited CT sections for the area of interest may be obtained to reduce the radiation dose. Intravenous contrast material administration may be required for cervical biopsy, especially to visualize the major vessels. The shortest approach should be considered and care should be taken to avoid major vessels or neural structures along the path.
3. Anesthesia

At our institute, the majority of the bone biopsies are performed under local anesthesia. General anesthesia is reserved for patients in the pediatric age group (under 18 years) or for lesions in a critical location such as those in cervical spinal lesions, especially C1 or C2 vertebrae, where the slight movement of the patient can lead to disastrous complications. Patients who cannot tolerate pain or are uncooperative would benefit from general anesthesia. Fasting duration for local anesthesia is 3 to 4 hours; for sedation, it is 6 hours, and for general anesthesia, it is 8 hours. Intravenous access should be secured before the procedure. Prophylactic antibiotics are not required.16 The procedure should be performed under sterile precautions. Once the needle entry site is identified, the skin should be prepared with cleaning agents such as chlorhexidine, alcohol, or betadine. The skin, subcutaneous layers, muscles, and periosteum are then infiltrated with a local anesthetic using a 22-gauge needle. The position of the needle is checked on the CT scan. If the needle tip is in the desired location, the local anesthetic drug is injected until the periosteum.17,18 For bone puncture, we use the bone biopsy needle (Murphy’s needle), either of 11G or 13 G needle is used and inserted safely under CT guidance. Fluoroscopy can be used in conjunction with CT, if available, whenever drilling is required for the sclerotic bone lesions.

4. Biopsy Technique and Needle Selection

Various types of needles are available for sampling of the tissues,19 such as needles for fine-needle aspiration (FNA), automatic/semiautomatic core biopsy needles, and the trephine needle system for bone biopsy. A combination of needles can be used, depending on the nature of the lesions.

Needles for FNA

These needles used for cytology are 20 to 22 G needles with a beveled tip and used for cutting the tissues.20 The needle is inserted into the lesion and then stylet is withdrawn. With the help of negative suction, the needle is moved to and fro (~15–30 times) in the lesion. The collected material is spread on a slide and fixed with formalin or air-dried. FNA needles have the advantage of obtaining the tissue sample with a minimum risk of complications. However, it is usually reserved for cases with a suspected tumor, recurrence, or aspiration of fluid collection. The main disadvantage of FNA over core needle biopsy is that FNA shows only cytological features of the lesion and not the tissue architecture.21

Automatic/Semiautomatic Core Biopsy Needles—(→ Fig. 2)

These are used for lesions that are easy to penetrate, such as lytic bone lesions or lesions with a soft-tissue component. These are available in automatic or semiautomatic or manual variants and are spring-driven devices with a cutting edge on one side. The coaxial needle system is preferred at our institute, which has a Trocar needle with diamond-shaped tip and an outer cannula. The coaxial biopsy needle system is preferred due to advantages such as obtaining a nonfragmented specimen, multiple cores with a single-needle pass, decreased procedure time, and minimizing the risk of complications such as bleeding.22 Cores obtained are used for cytology, histopathology, molecular analysis, and microbiological analysis.23

Bone biopsy needles—(→ Fig. 2)

The Murphy’s bone biopsy needle (Cook Medical, Bloomington, IN) used in our institute is a large-bore needle with a diamond cutting edge on the inner trocar and serrated tip on the outer cannula. The cannula and trocar fit into each other snugly with an interlocking handle. These needles are used to obtain a bone specimen for histopathology, molecular analysis, and microbiological analysis. Murphy’s bone biopsy needle (Cook Medical, Bloomington, IN) is used as a coaxial system to obtain tissue samples using Ackermann needle (Cook Medical, Bloomington, IN) as the preferred needle. Using the bone biopsy needle requires special skill and a good amount of practice. This needle needs to be drilled in the bone in a clockwise and anticlockwise rotary action direction till the starting of the lesion is reached. The inner stylet is removed, the Ackermann needle is introduced into the lesion in a similar fashion to trap the tissue within the cannula, and the cannula is removed at one go. The bone core entrapped within the Ackermann cannula is pushed out using the inner stylet and the specimen obtained is sent for analysis.

Accuracy of the obtained sample is higher for neoplastic lesions compared with benign lesions like infections and inflammations.24 The yield of the biopsy depends on the selection of a coaxial needle system, depending on the type of lesion (soft tissue, lytic, sclerotic or mixed), location of the lesion (vertebra, intervertebral disc, paraspinal soft tissues), and method of the specimen acquisition.25,26 For lytic lesions or lesions with soft-tissue component, automatic/semiautomatic core needle is used. The combination of a bone biopsy needle along with core biopsy needle is useful when the intact cortex and the lytic lesion is present. The intact cortex of the bone can be drilled with the bone biopsy needle and then the core biopsy needle can be advanced into the lytic component28(→ Table 1). Larger-core bone biopsy (Murphy’s or Ackerman needle) is preferred over needle aspiration needle for sclerotic lesions, since larger size specimen will result in a higher diagnostic accuracy. The Ackerman needle has the advantage of a coaxial system to obtain multiple cores, but the main disadvantage of this needle is that it causes sample size crushing artifact, leading to inconclusive
results. No association has been found between the radiological appearance of lesions and sufficient biopsy material or biopsy success.\textsuperscript{29} Accurate route planning and proper hardware selection are the keys to biopsy success with minimal complication.

5. Approaches and technical considerations

Different approaches depending on the vertebral level

1. Cervical vertebra\textsuperscript{30,31}
   a. Anterolateral–cervical body from C3 to C7 (\textit{\textbullet} Figs. 3, 4).
   b. Posterior–for spinous process.
   c. Posterolateral–large articular masses and posterior elements (\textit{\textbullet} Fig. 5).
   d. Open mouth (transoral)–or lesions in C1, C2 (\textit{\textbullet} Fig. 6).

2. Thoracic\textsuperscript{31,32}
   a. Classical transpedicular–vertebral body, pedicle (\textit{\textbullet} Fig. 7).
   b. Trans costovertebral–vertebral body, intervertebral disc.
   c. Paraspinal oblique/parapedicular–intervertebral disc (\textit{\textbullet} Fig. 8).
   d. Intercostal–vertebral body masses or paravertebral masses.
   e. Transforaminal–vertebral body lesion (\textit{\textbullet} Fig. 9).
   f. Para laminar or tangential–spinous process (\textit{\textbullet} Fig. 10).

3. Lumbar\textsuperscript{31}
   a. Classical transpedicular–vertebral body (\textit{\textbullet} Fig. 11).
   b. Posterolateral.
   c. Lateral.
   d. Paralaminar or tangential (\textit{\textbullet} Fig. 10).
   e. Parapedicular.

Table 1 Needle used in different types of lesions with advantages of each

<table>
<thead>
<tr>
<th>Lesion type</th>
<th>Needle required</th>
<th>Advantages</th>
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<tbody>
<tr>
<td>Lytic lesion/soft tissue/lytic bone</td>
<td>Coaxial core biopsy needle (semiautomatic/</td>
<td></td>
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<tr>
<td>with soft tissue</td>
<td>automatic)</td>
<td>- Easy to penetrate</td>
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<td></td>
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<td>- Intact specimen</td>
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<td></td>
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<td>- Multiple cores with single path decrease the procedure time</td>
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<td>- Less risk of complications</td>
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<tr>
<td>Sclerotic/mixed lytic sclerotic lesion</td>
<td>Bone biopsy needle</td>
<td>- Larger specimen with bigger size cores.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Multiple cores with the help of Ackermann Needle.</td>
</tr>
<tr>
<td>Intact cortex with lytic lesion</td>
<td>Combination of needles (bone biopsy and</td>
<td>- Intact cortex needs to be drilled with Bone biopsy and soft tissue biopsied</td>
</tr>
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<td></td>
<td>core biopsy needle)</td>
<td>with core biopsy needle.</td>
</tr>
<tr>
<td>Soft tissue for metastasis and aspiration of fluid</td>
<td>FNA needles</td>
<td>- To prove metastasis in known primary</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Aspiration of fluid for culture</td>
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<tr>
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<td>- Less risk of complications</td>
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Abbreviation: FNA, fine-needle aspiration.
1. Cervical vertebra (►Fig. 13 a).
Anterolateral and posterolateral approaches are commonly used for cervical vertebral bone biopsies from C3–C7.

2. Thoracic vertebra (►Fig. 13 b)
The biopsy of a thoracic vertebra is performed using CT and/or fluoroscopic guidance. While transpedicular, transcostovertebral, and foraminal approaches are used to biopsy body of the thoracic vertebra, transcostovertebral and paraspinal oblique pathways are used to sample the intervertebral disc. For the lesions located in the paraspinal or depending on the site of the lesion. When using the anterolateral approach, one must avoid the major vessels, that is, carotid arteries and jugular vein in the carotid space, while esophagus, trachea and pharynx in the midline. The major vessels and sternocleidomastoid muscle are retracted laterally and the needle is introduced between the airway and carotid vessels to the vertebra. Another approach is hydrodissection (instilling normal saline/dextrose to displace organ and/or vessel when they are close to each other, so as to facilitate a smooth pathway till the lesion when no safe route is possible) between the major vessels and thyroid gland to reach the lesion in the cervical vertebral body. An open mouth or transoral approach is used for lesions in the odontoid process or C1–C2 vertebra.30,31 If the anterolateral or posterolateral approach is used, the patient’s head should be tilted on one side to minimize movement of the patient. The posterior approach is used for the spinal process lesion, taking care of the spinal cord, while the posterolateral approach for lesions of the lateral masses or posterior elements. The needle trajectory should be directed away from the major vessels and spinal cord.

3. Lumbar vertebra (►Fig. 13 c).

4. Sacral.
a. Anterior–presacral region.
b. Posterior (►Fig. 12).
c. Posterolateral (►Fig. 12).
d. Transsacral.

4. Sacral.

a. Anterior–presacral region.

b. Posterior (►Fig. 12).

c. Posterolateral (►Fig. 12).

d. Transsacral.

1. Cervical vertebra (►Fig. 13 a).
Anterolateral and posterolateral approaches are commonly used for cervical vertebral bone biopsies from C3–C7,
lateral thoracic vertebral regions, costovertebral or intercos-
tal approach can be used.

While using a transpedicular biopsy, fluoroscopy allows
real-time imaging of the needle passage. The transpedicu-
lar approach is the safest approach for vertebral body
biopsy.33,34 The long transverse process may limit the ac-
cessibility of thoracic vertebral lesions; hence, the posterolat-
eral or parapedicular or intercostovertebral approaches are
preferred.35,36 The limitations of the transpedicular approach
include are difficult penetration of the bony cortex, the pos-
sibility of injury to the medial and inferior walls of the pedi-
cle, spinal canal structures, nerve roots and inability to reach
the intervertebral disc.37 In such situations, transfemoral or
transcostovertebral discal biopsy becomes advantageous.
In the transcostovertebral approach, the needle enters between
the tubercle of the rib and the transverse process and requires
drilling through the facet joint. This approach keeps the nee-
dle away from the pleura or lung laterally and exiting nerve
roots and pedicle medially.

A paralaminar or tangential approach is used for the
lesions involving the neural arch structures. The advantage is
the direction of needle trajectory being away from the neural
structures. This approach depends on the location lesion and
should be appropriately planned for each patient.

3. Lumbar vertebra (<Fig. 13 c>)

The transpedicular approach is commonly used for biopsy
for vertebral body and pedicular lesions biopsy. This approach
is similar to that for thoracic vertebra. The lateral approach in
lateral decubitus can be used when the patient is unable to
lie down in a prone position, and this can be used for ver-
tebral body, disc and paraspinal soft tissues.38 The approach
to biopsy should be such that the skin and the entire biopsy
tract can be easily excised during the surgical resection of
the tumor and hence the skin entry should be at the site of the
potential surgical incision.

4. Sacral Vertebra

CT-guided biopsy of the sacral lesions is better as com-
pared with fluoroscopic-guided, because of the complex
structural anatomy of the sacrum.

a. Presacral and anterior vertebral lesion—Anterior approach
is preferred, but at times this anterior approach may be
difficult, because of bowel loops or major vessels in the
path. A longer length of the needle may help in such situ-
ations. Another method is the transsacral approach from
the posterior aspect, which uses a combination of the nee-
dles. A bone biopsy needle is used to drill the bony cortex
from posterior to the anterior surface, and after removal of
the inner stylet, the core biopsy needle is used to obtain a
sample from the soft tissue.

b. Sacral ala lesions—Posterior or posterolateral approaches
may be used.

c. Spinous process—Posterior or posterolateral approaches
may be used.

5. Postprocedure care:

If the procedure is performed under local anesthesia,
the patient should be monitored in the recovery room. The
vitals and biopsy site should be checked every 15 minutes
for 1 hour, and then every 30 minutes for 2 hours for any
complications. If the procedure is performed under general
anesthesia or deep sedation, monitoring should continue till
the patient is weaned off the effect of anesthetic drugs. If a
posterior approach is used then the patient should lie in a
supine position during the recovery. Antiplatelet drugs such
as clopidogrel can be restarted after 6 hours of the proce-
dure, if using 75 mg dose, while others such as LMWH can
be restarted after 12 hours and direct oral anticoagulants
(DOACs) after 24 hours.39 A chest radiograph may be per-
formed to rule out pneumothorax following thoracic ver-
tebral biopsies if the procedure is done under fluoroscopic
guidance. Patients may be given analgesics for pain relief.

Outcomes

The diagnostic accuracy of the CT-guided biopsy is in the
range of 70 to 93% in the published literature.40-42 The ac-
curacy is approximately 90% for malignancies and metastases as
compared with around 80% for benign tumors. Also, primary
malignancies have a lower diagnostic yield as compared with
metastases. Rimondi et al showed that the diagnostic accu-
ragy of the biopsies is lower in the cervical region as com-
pared with lumbar or thoracic regions, due to the small size
of the lesions and difficult access.24 Since the size of the cervi-
cal vertebra body is small, there are technical difficulties, and
nodenegative biopsies are more common.31 Cystic, sclerotic,
and necrotic lesions have lower diagnostic yields.5 In a study by
Yang et al, lytic (88%) or mixed (84%) lesions showed the
diagnostic yield as compared with sclerotic (67%) or isodense (61%) lesions. Sclerotic lesions have low cellularity and reactive new bone formation, which may require the use of the drill, leading to crushing artifacts and decalcification prior to processing. The diagnostic yield of lesions bigger than 2 cm is higher (84%) compared with smaller lesions (52%). A repeat biopsy may be required when histopathology results are nondiagnostic. However, this should be preceded by an imaging review for the possibility of the lesion being benign or inflammatory.

Complications

A CT-guided percutaneous biopsy is safer compared with open surgical biopsy. Lower rates of complications and shorter hospital stays make it the procedure of the choice. Although radiation can be a problem with CT guidance, the benefits outweigh the risks. According to a metaanalysis, the complications of percutaneous bone biopsy are in the range of 0 to 10%. Acute complications may occur during or immediately after the procedure. One of the common acute complications includes bleeding due to vascular injury. Arterial bleeding is life-threatening and requires immediate interventions. Venous bleeding presents late in the form of paravertebral oozes. When a hypervascular tumor, arising from the pedicle or posterior vertebral body cortex and extending into the central canal, bleeds after the biopsy, it may result in cord compression. Other complications include nerve roots injury, leading to paraplegia and pnumothorax during a thoracic vertebral biopsy. Late complications include infection, tumor spread, and vertebral fracture.

Limitations

The two main limitations of vertebral biopsy include sample crushing and insufficient material, leading to inconclusive results. Most of the rebiopsies are seen in sclerotic, cystic, or necrotic lesions with low yield rates despite repeated biopsies. Another reason for low yield is the presence of a benign lesion as opposed to a malignant lesion, or when the patient is on broad-spectrum antibiotics prior to sampling of suspected infective focus in the bone.

Conclusions

CT-guided percutaneous biopsy of the spine is a safe and effective procedure. CT helps in identifying and targeting the lesions accurately and minimizing the complications. Sound radiological knowledge, knowledge of the hardware, and assessment of lesion anatomy on prior images are important. Anatomical landmarks are important to identify the critical structures and planning the appropriate approach.

Conflict of Interest
None declared.

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