Diagn Interv Radiol 2020; 26:143–146

INTERVENTIONAL RADIOLOGY

TECHNICAL NOTE

Approach-based techniques of CT-guided percutaneous vertebral biopsy

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ABSTRACT

Magnetic resonance imaging (MRI) plays an important role in the characterization of vertebral lesions. Even if latest improvements in MRI permit to understand and suspect the nature of vertebral lesions and positron emission tomography computed tomography (PET-CT) gives information about lesion metabolism, biopsy is still needed in most cases. CT-guided percutaneous vertebral biopsy is a minimally invasive, safe and accurate procedure for definitive tissue diagnosis of a vertebral lesion. CT-guided vertebral biopsy is often the best alternative to a surgical biopsy. The purpose of this technical note is to discuss the approach-based techniques for CT-guided percutaneous vertebral biopsy.

Histopathological confirmation of a vertebral lesion can be done either by open surgical method or by a minimally invasive (percutaneous imaging-guided) method. Open surgical biopsy in a vertebral lesion carries a significant risk of morbidity, the possibility of spillage or contamination of adjacent tissue planes and postoperative complications (1, 2). Percutaneous imaging-guided biopsy of a vertebral lesion can be performed under the guidance of computed tomography (CT). Percutaneous CT-guided biopsy of the vertebral lesion is a safe, effective and accurate diagnostic tool and is favored over open techniques when feasible (3). The common indications for vertebral biopsy are histological characterization of focal vertebral lesion; characterization of suspected as well as known spinal metastasis, receptor/immunohistochemical analyses; diagnosis of a suspect spondylodiscitis, histopathology and microbiological test; diagnosis of atraumatic vertebral fractures of unknown origin with differentiation between osteoporotic, neoplastic, and inflammatory fractures (4–6). This technical note will highlight the approach-based techniques of CT-guided percutaneous vertebral biopsy.

Technique

There are multiple approach-based techniques for CT-guided biopsy of vertebral lesions. These techniques depend on multiple factors including the following: location of the lesion within the vertebrae; focal or diffuse lesion; location within the spinal column, i.e., cervical, thoracic or lumbar spine location; vertebra plana; and associated soft tissue mass. CT-guided vertebral biopsy is usually performed under conscious sedation or local anesthesia. General anesthesia is required in patients with comorbidities, patients unable to lie prone, and pediatric patients.

The key principles for successful and safe CT-guided vertebral biopsy are best denoted in form of 3 Ps: "planning" of successful biopsy, "positioning" of the patient to achieve optimum biopsy plane and "protection" of the vital vascular and neural structures in the trajectory of a biopsy needle.

Plan: Appropriate selection of the lesion, shortest possible feasible route, entry point and angle of the needle pathway are important factors to consider when planning a vertebral lesion biopsy. In the case of multiple lesions, the lesion which is the safest and most likely to yield a diagnosis is selected. This is often the largest and most superficial lesion. Whenever there is associated soft tissue component along with bony lesion, both bony and soft tissue

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Received 11 June 2019; revision requested 05 July 2019; last revision received 18 July 2019; accepted 29 July 2019.

Published online 13 January 2020.

DOI 10.5152/dir.2019.19268

You may cite this article as: Kumar Singh D, Kumar N, Kalyan Nayak B, et al. Approach-based techniques of CT-guided percutaneous vertebral biopsy. Diagn Interv Radiol 2020; 26:143–146.

components should be biopsied simultaneously. For suspected infective spondylodiscitis, it is preferable to sample both bone and disc. For lesions that require oblique needle trajectory, CT gantry can be tilted in the craniocaudal direction parallel to the desired needle trajectory and then the needle is aligned with the CT gantry laser beam to guide the needle access to the target, maintained within a single CT slice.

Position: CT-guided percutaneous vertebral biopsy for thoracic and lumbar vertebrae are usually performed in a prone position. For cervical vertebrae, patient positioning depends upon the location of the cervical vertebral lesion, the approach of biopsy and the skill set of the operator. For posterolateral and direct posterior approaches, the patient is placed prone on the table. For the direct lateral approach, the patient is placed in the decubitus position with side of the lesion upwards. For the anterolateral approach, the patient is placed in a supine position (7).

Protection: Safeguarding the key anatomical structures within the biopsy path is achieved by planning and selecting such needle pathway that it does not cross different anatomical compartments, protecting the major neurovascular structures, spinal canal, and visceral cavities.

Main points

- Nowadays imaging-guided (commonly CT-guided) percutaneous vertebral biopsy is the first diagnostic tool (safe and diagnostic in a high percentage of patients) preferred to open biopsy for definitive diagnosis of the vertebral lesion.
- The key to a successful and safe CT-guided percutaneous vertebral biopsy depends upon the rule of 3 Ps: Plan, Position, and Protection (planning for appropriate technique; positioning the patient for appropriate approach; and protection of vital neurovascular structures).
- The various approaches of CT-guided percutaneous vertebral biopsy depend upon multiple factors including the following: location of the lesion within the vertebrae; focal or diffuse lesion; cervical, thoracic, or lumbar spine location; vertebra plana; and associated soft tissue mass.
- CT-guided percutaneous biopsy should also be taken from the pedicle if the vertebral body is markedly collapsed with the involvement of pedicle and dual biopsy should be undertaken from the involved vertebra and the associated soft tissue when present.

We discuss approach-based techniques of CT-guided percutaneous vertebral biopsy and the major determinants of successful, secure biopsy in each approach as done in our institution with written informed consent obtained from the patients before the procedure. The various approaches of vertebral biopsy include:

1. Transpedicular technique: This is the preferred approach to vertebral biopsy and can be used anywhere in the spine with appropriate sized needles when it is feasible. This approach reduces the risk of bleeding and seeding. This is the most common approach for lumbar vertebral biopsy (Fig. 1a). Merits of percutaneous CT-guided transpedicular biopsy include shorter needle tract, anatomy of transverse process and the mammillary process joining at an acute angle (Fig. 1b, *red star*), thus guiding the needle tip toward the pedicle with the biopsy needle perpendicular to the cortex of the bone at the point of entry, reducing the chance of slippage and presence of thin cortical bone along the posterior aspect of the pedicle.

2. Posterolateral extrapedicular technique: This approach is performed for lumbar vertebrae when the transpedicular approach is not feasible, e.g., open wound or scar in posterior cutaneous or subcutaneous plane, thin lumbar pedicles in some subjects (Fig. 2a). The trajectory of the needle is through psoas or posterior to psoas muscle to enter into the vertebral body (Fig. 2b). Precaution is taken to avoid needle maltracking posteromedially to the neural foramen and anteromedially to aorta/iliac arteries. There can be a risk of potential injury to aberrant spinal artery/radicular artery with this approach, and there is an increased risk of retroperitoneal hematoma/pseudoaneurysm formation (8).

3. Superior costotransverse technique: This approach is performed for biopsy of mid and lower thoracic vertebrae in

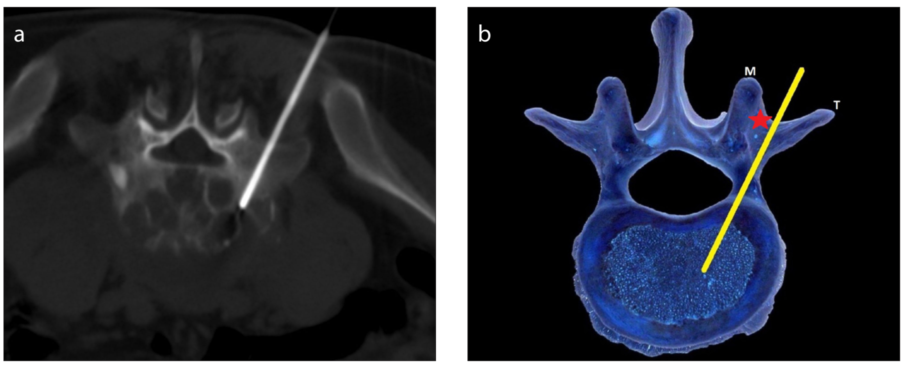

Figure 1. a, b. CT-guided percutaneous transpedicular lumbar vertebral biopsy. Axial CT image **(a)** demonstrates a biopsy needle through the pedicle into the vertebral body. Schematic image **(b)** highlights the anatomical relationship of the mammillary body, transverse process, and pedicle of a lumbar vertebra (*red star* indicates "V" shaped notch between mammillary body and transverse process; *solid yellow line* shows the trajectory of the biopsy needle). M, mammillary process; T, transverse process.

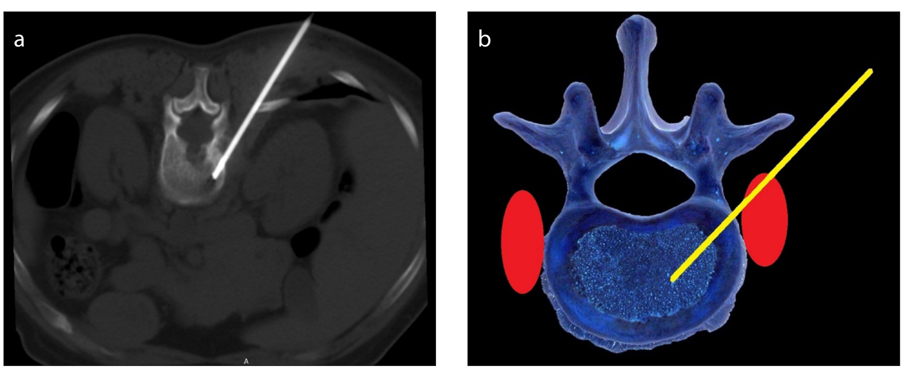

Figure 2. a, b. CT-guided percutaneous posterolateral extrapedicular lumbar vertebral biopsy. Axial CT image **(a)** demonstrates needle trajectory outside the pedicle into the vertebral body. Image **(b)** demonstrates schematic representation of needle trajectory (*solid yellow line* shows the trajectory of the biopsy needle; *oval red structures* indicate the psoas muscle).

which vertebral body lesion is approached through superior costotransverse joint space (Fig. 3a). In these vertebral segments, the pedicle is often wide enough for the transpedicular approach but it requires drilling through the facet joint. The superior costotransverse approach is an easier technique than drilling through the facet joints for the transpedicular approach. The anatomical basis of this approach is that superior costotransverse joint space serves as an excellent needle entrance guide into vertebral body avoiding pedicle medially and lung or pleura laterally (Fig. 3b, *red star*). The superior costotransverse approach cannot be performed in patients with costotransverse arthrosis or fusion wherein the gap between the rib and transverse process is obliterated. In such patients posterolateral approach (lateral to costotransverse joint) is used after instilling sterile normal saline into extrapleural space to push lung and pleura laterally and to create a safe space between pleura and the rib.

4. Inferior costotransverse technique: This approach is performed in upper thoracic vertebral biopsy in which the vertebral lesion is approached through inferior costotransverse joint space (Fig. 4a, 4c). In these vertebral segments, the pedicle is usually wide enough but the inferior costotransverse technique is easier than drilling through the inferior part of the facet joint to get into the lesion for a transpedicular approach. The superior costotransverse gap is very narrow as well as the transverse process is more superiorly directed in upper thoracic vertebrae excluding a superior costotransverse approach. Posterolateral approach (lateral to the costotransverse joint) carries increased risk of lung or pleural injury. The only potential gap to safely approach upper thoracic vertebral lesion is through inferior costotransverse joint space (Fig. 4b). There can be a risk of lung injury if the needle trajectory is more anterolateral and risk of nerve root injury if the needle trajectory is more caudal.

5. Pedicular biopsy: This approach is performed when the vertebral body is collapsed with the involvement of the pedicle (Fig. 5a,

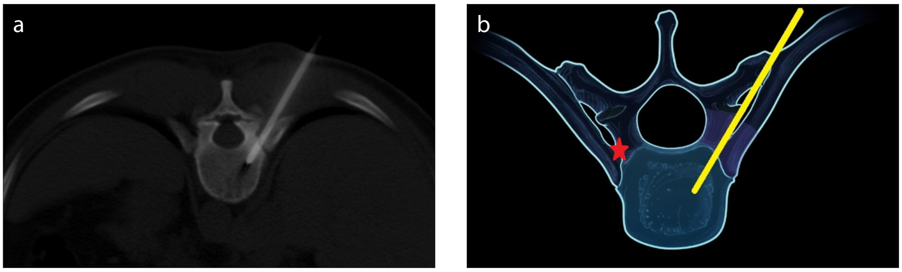

Figure 3. a, b. CT-guided percutaneous superior costotransverse approach of thoracic vertebral biopsy. Axial CT image **(a)** demonstrates the superior costotransverse approach of vertebral biopsy with a needle into the vertebral body through superior costotransverse joint space. Image (**b**) demonstrates the schematic representation of the needle trajectory (*red star* indicates the gap between the rib and superior surface of the transverse process; *solid yellow line* shows the trajectory of the biopsy needle into the vertebral body through the superior costotransverse joint).

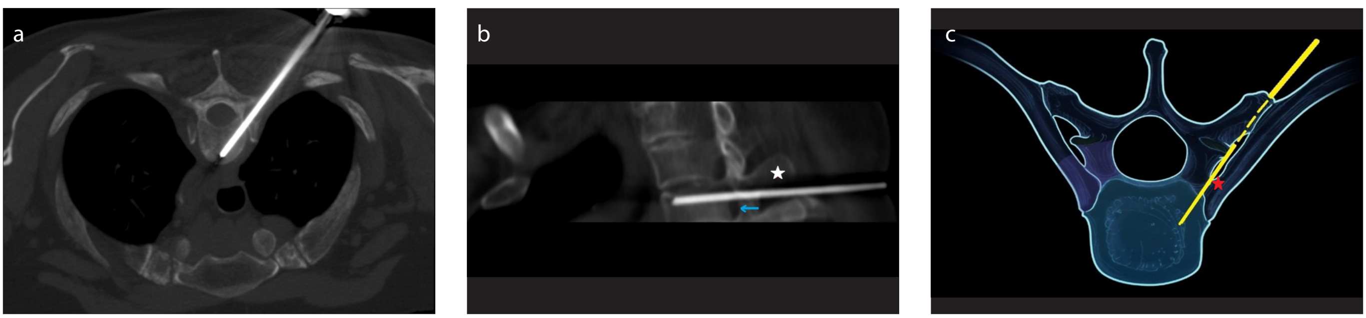

Figure 4. a–c. CT-guided percutaneous inferior costotransverse approach of upper thoracic vertebral biopsy. Axial CT image **(a)** demonstrates needle entry into the vertebral body through an inferior costotransverse joint space. Sagittal reformatted CT image **(b)** demonstrates needle trajectory inferior to the transverse process *(white asterisk)* and superior to neural foramina *(blue arrow)*. Image **(c)** demonstrates the schematic representation of the needle trajectory (*red star* indicates the gap between the rib and inferior surface of the transverse process; *solid yellow line* shows the trajectory of the biopsy needle into the vertebral body through inferior costotransverse joint; *broken yellow line* shows the trajectory of the biopsy needle inferior to transverse process).

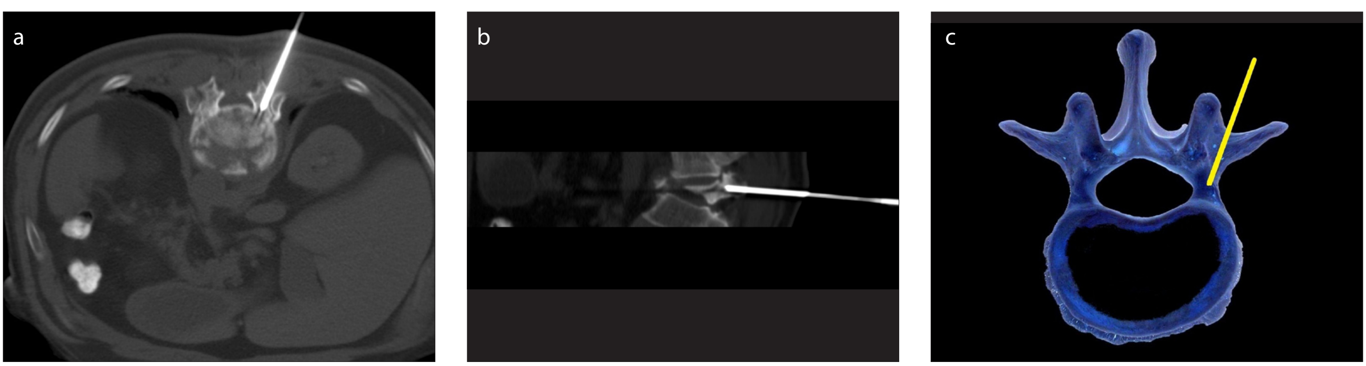

Figure 5. a–c. CT-guided percutaneous pedicular biopsy in a collapsed vertebral body. Axial CT (**a**), sagittal reformatted CT (**b**), and schematic representation **(c)** demonstrate biopsy needle trajectory into the pedicle (*solid yellow line* represents the needle trajectory).

5b). Apart from the biopsy of the collapsed vertebral body, biopsy should also be performed through the involved pedicle for maximum diagnostic yield (Fig. 5b, 5c). This biopsy is preferably done in collapsed lumbar, lower dorsal vertebrae with intact medial and inferior cortex to avoid the risk of the spinal cord, cauda equina or exiting nerve roots damage.

6. Anterolateral or lateral technique: This approach is usually performed for cervical vertebral body biopsy with patient in supine position but the presence of trachea and pharynx in midline, esophagus in left paramedian position, carotid artery and internal jugular vein (IJV) in carotid space anterolaterally and vertebral artery in foramen transversarium posterolaterally warrants such biopsy to be performed by experienced hands to avoid major complications. The potential narrow space between IJV and anterior margin of foramen transversarium is one of the safe routes to approach the body of cervical vertebrae, preferably from the right side (to avoid esophageal injury). About 30–50 mL of nonionic intravenous iodinated contrast is injected before the procedure to outline key vascular structures, i.e., carotid artery-IJV-vertebral artery to prevent inadvertent vessel injury. Through the lateral approach, the needle tip is aimed at the anterior surface of foramen transversarium (posterior to IJV) and after confirming the needle tip at the desired location, the needle is advanced further into the vertebral lesion (Fig. 6a, 6b).

7. Dual biopsy: This biopsy is done for soft tissue mass associated with adjoining vertebral lesion. The biopsy is done both from the soft tissue mass (Fig. 7a, 7b) and the vertebral lesion (Fig. 7c, 7d) in one sitting. The rationale behind biopsy from two targets is to maximize the diagnostic yield in a single puncture.

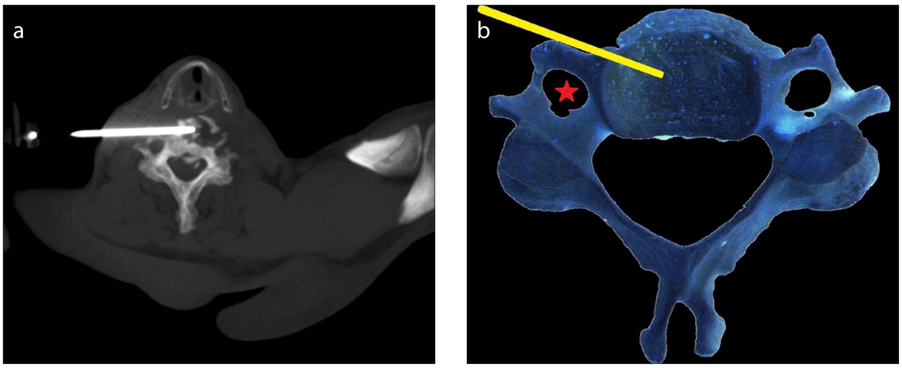

Figure 6. a, b. CT-guided percutaneous anterolateral/lateral approach of cervical vertebral biopsy. Axial CT image **(a)** demonstrates the biopsy needle into vertebral lesion through an anterolateral/lateral approach. Image **(b)** demonstrates schematic representation of needle trajectory anterior to foramen transversarium (*solid yellow line* indicates the biopsy needle trajectory; *red star* shows the foramen transversarium).

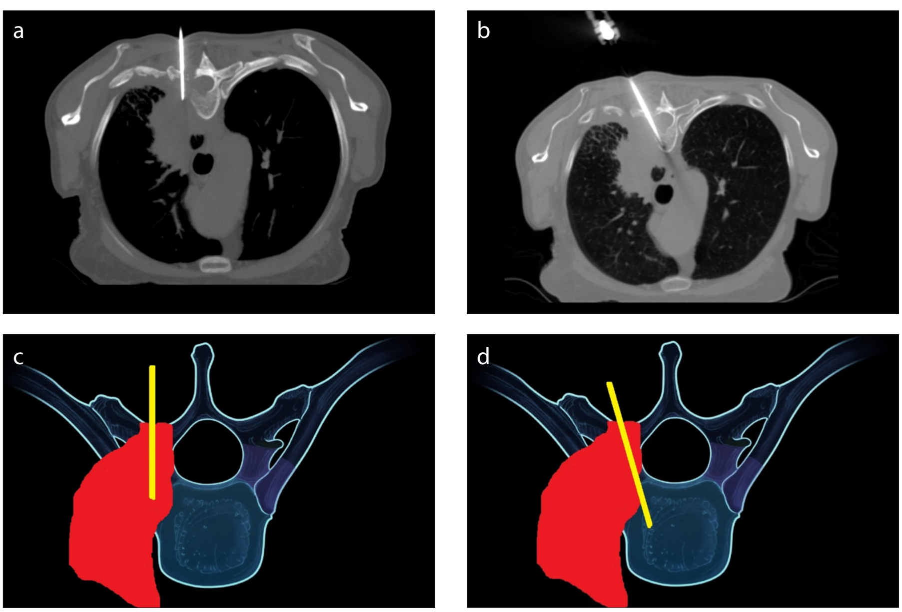

Figure 7. a–d. CT-guided percutaneous dual vertebral and soft tissue biopsy. Axial CT images **(a, b)** demonstrate biopsy of the soft tissue mass **(a)** and biopsy of the infiltrated vertebrae **(b)**; Schematic representations **(c, d)** demonstrate biopsy from the soft tissue mass as well as from vertebral lesion (*solid yellow line* shows the biopsy needle trajectory and *solid red structure* shows the soft tissue mass).

Conclusion

The best alternative to open surgical vertebral biopsy for definitive diagnosis of the vertebral lesion is CT-guided percutaneous vertebral biopsy, which is a safe, accurate, and outpatient procedure. The success of the procedure with utmost safety hinges on the rule of 3 Ps, step by step meticulous planning and tailoring of the technique based on the vertebral level involved. Using minimally invasive approach-based techniques discussed, the need for open surgical biopsy can be obviated.

Conflict of interest disclosure

The authors declared no conflicts of interest.

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