Chapter 10
FNAC and Biopsy Techniques in TB Spine

Chirag Kamal Ahuja and Bharat Hosur

Abstract The image-guided fine needle aspiration (FNA) and biopsy are of utmost importance in the effective management of spinal tuberculosis (TB), providing a definitive diagnosis. The spinal TB mimics like brucellosis, pyogenic infections, post-traumatic spinal degeneration, lymphoma, metastases, etc. may bear a close resemblance in clinico-radiological profile. Meticulous planning with a detailed pre-procedural clinical assessment, contrast-enhanced MRI, and attention to serial imaging and clinical course of the disease is crucial. Screening the patients for coagulopathies, neurological deficits requiring urgent surgical treatment in synchronization with the treating team averts complications. Thorough knowledge of the regional anatomy in the target area of biopsy bundled with a judicial choice of hardware and modality of imaging for guidance ensures precise access as well as the optimal yield of the tissue sample. The transpedicular coaxial approach is the commonest method used for the dorsolumbar spine, through the "bull's eye view of pedicle" if fluoroscopic guidance is used. Ultrasound or MRI guidance can be used in apt locations in pregnant or pediatric patients. Optimal patient comfort using local anesthesia, sedation and apt positioning, observing radiation safety measures and post-procedural care is sine-qua-non for patient safety and satisfaction as well as an efficient workflow.

Keywords Aspiration · Biopsy · CT guided · Spinal · Tuberculosis

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10.1 Introduction

The spinal FNAC or biopsy can be an effective adjunct to the clinical management of spinal tuberculosis when strategically planned with meticulous pre-procedural imaging, technical details of the procedure and post-procedural care. The coordinated team efforts between the operator and the referring clinician without communication gaps is a sin-a-qua-non for the meaningful outcome of the procedure as well as the patient safety. The attendants of the patient need to be kept informed at all the stages of the procedure apart from the initial detailed informed consent, to enhance patient satisfaction.

Identity of the patient, side and location of the affliction, correlation with the most recent imaging prior to the procedure and referring to the timely clinical notes bear immense medico-legal importance as well as save everyone from the unnecessary mismatch between the expected and performed procedures. Strict protocols regarding the vertebral numbering and labeling the levels craniocaudally on the pre-procedural imaging films can help to prevent inappropriate needle placement. The GATA classification (GATA = Gulhane Askeri Tip Akademisi) from the Gulhane Military Medical Academy provides relatively simplistic guidance for the surgical or interventional management approach of spinal tuberculosis [1]. A clinically stable patient without any neurological deficit, with the involvement of a single vertebra or single disc with no collapse and no abscess, is classified as Type 1A and is the right candidate for FNAC/Biopsy followed by medical management. The presence of abscess and/or involvement of two vertebral levels, which is Type 1B, mandates abscess drainage with debridement. Also, the presence of a stable spinal deformity is labeled Type-2 and treated with a surgical fusion of the vertebrae, while the unstable deformity, especially with neurological deficits, is urgently managed with surgical decompression.

The needle biopsy/microbiological confirmation is of utmost importance even in presence of obvious imaging features suggestive of spinal tuberculosis, especially in the endemic regions, due to the close resemblance of the clinico-radiological profile of the mimics [2]. Brucellosis, pyogenic infections, rheumatoid arthritis, post-traumatic spinal degeneration, lymphoma, metastases, and rarely, Rosai-Dorfman disease form the close differential diagnosis for spinal TB. The imaging phenotypes may be further distorted with immunocompromised status, coexisting infection with malignancy, and multifocal disease. Also, the locoregional and temporal variations in the presentations and natural history of the spondylodiscitis similar to the spinal TB mandate the definitive evidence before starting the non-tubercular drug therapy [3]. In a recent study, the MRI was shown to have a sensitivity of 85.71% and a specificity of 86.48% for the diagnosis of spinal tuberculosis. The initial biopsy had a sensitivity of 71.42% and specificity of 100% for the diagnosis of infection [4]. The image-guided needle-based microbiological diagnosis is shown to provide reliable, timely, and clear management decisions, avoiding unnecessary diagnostic dilemmas, delays, and failures in the treatment [5].

10.2 Anatomical Factors

The soft tissue spaces around the spine from skull base to coccyx can be accessed for aspiration cytology or biopsy safely adhering to the locoregional peculiarities at various spinal segments. The cervical spine has relatively smaller vertebral bodies with broader posterior elements that lie nearly in the same plane. Both anterolateral as well as posterolateral approaches are feasible in the cervical spine provided the needle path avoids the carotid space. The cervical exiting nerves traverse anteriorly nearly in the same plane of the respective discs, unlike the obliquity seen in the subsequent caudal levels. Also, the vertebral arteries, veins, and sympathetic nerves traverse the transverse foramina of the cervical vertebrae.

The dorsal spine, a relatively common site for tubercular involvement, has lungs and mediastinal vital structures in the immediate vicinity of the prevertebral space. The descending aorta on the left side is usually closely abutting the vertebral bodies and the discs upto the D10 level. The adjacent pleura overlying the lungs are pain-sensitive structures and can accumulate dangerous pneumothorax if breached inadvertently. The left atrium is the cardiac chamber closest to the spine and can be injured with unsafe needle access.

The lumbar spine, by far the technically least difficult location for needle access is also the commonest site for aspiration or biopsy. Owing to the larger size of the vertebrae and abundance of paraspinal muscle and subcutaneous fat, the delineation of the tissue planes and the needle access path is relatively simpler [6]. However, the presence of abnormal curvature due to kyphoscoliosis may render the target tissue inaccessible for safe passage of the needle. The lumbar curvature can be manipulated by placing the pillows under the hip or chest in addition to the CT gantry tilt to achieve a feasible cross-sectional plane for the optimal needle visualization. Inadvertent injury to the obliquely traversing lumbar nerve plexus and the closely hugging sympathetic chain can be carefully avoided by choosing the apt paramedian distance from the midline at the skin entry. The sacral lesions being in close proximity to the recto-sigmoid parts of the large bowel are amenable for external and endorectal access options. There is also a risk of gut perforation and contamination of the sample. The peculiarities of the regional anatomy need focused heed on a case-to-case basis before the invasive procedure.

10.3 Pre-Procedural Evaluation

The clinical inputs regarding the spinal localization, timeline, and severity of the illness should be elicited in detail. Comorbidities, immune status, and bleeding/clotting disorders should be meticulously recorded. The serial imaging, including the spinal radiographs, CT and contrast-enhanced MRI images, should be reviewed along with the chest and abdominal imaging if available. Only the most recent MRI (performed within two weeks before the procedure) is to be relied upon for planning the needle access. Pre-procedural contrast-enhanced MRI with axial and coronal reformats, preferably done in the same center performing the procedure, are to be stressed upon; since the canulation of the pathological site may distort the imaging appearance.

The patterns of vertebral involvement in spinal TB can be paradiscal (via spinal arteries), central (along the venous plexus of a single vertebra), anterior marginal (subligamentous spread along anterior longitudinal ligament and adjacent periosteum), posterior-involving only the posterior elements (via external venous plexus or direct contiguous spread), synovial (usually around the craniovertebral junction (CVJ), spread via the synovial arteries) and multilevel or skipped lesions along the Batson's venous plexus [7, 8]. The commonest imaging features typical for spinal TB are subligamentous spread to more than two spinal levels, enhancing paraspinal components of the spondylodiscitis with or without sparing the intervertebral disc [9]. Identification of the sinister imaging patterns that need urgent surgical management without the prior FNAC and locating the site of best possible diagnostic yield are the main advantages of the contrast-enhanced MRI, without the risks of radiation hazards.

Pre-procedural PET/PET-CT in the presence of multilevel and multifocal disease is essential, especially when the imaging features are not conclusive of spinal tuberculosis or a previous image-guided needle biopsy has been inconclusive. The whole-body PET adds the non-spinal target sites for a guided biopsy which is vital when the spinal target access is difficult. The conundrum of PET-CT in hypermetabolic inflammation like spinal TB is about the wide range of uptake values that can also have temporal variations. The cutoff maximum Standardized Uptake Value (SUVmax) in spinal TB has been reported to be as low as 2 and as high as 21 in tuberculosis [10]. No definite single cutoff value discriminating the spinal TB from the mimics has been established. Thus, despite being a very sensitive modality, the lack of its specificity in a hypermetabolic spinal lesion on PET makes the needle biopsy a sine-qua-non for effective treatment.

The spinal needle biopsy or aspiration is an invasive procedure and it should not be planned in isolation but in consultation with the managing team consisting of a Neurosurgeon, Neurologist, Interventional Radiologist & Pathologist. The contraindications (Table 10.1) and risk factors (Table 10.2) associated with the procedure

Table 10.1 Contraindications to image-guided percutaneous biopsy

Absolute
Uncorrected bleeding diathesis
Platelet count <50,000/mm3
Acute cord compression
Relative
Lesions closely abutting or encasing aorta / major vessels
Coexistent vascular malformations
Small dimension (<5 mm in diameter)
Lesions in other locations that are safer to biopsy
Noncooperative patient
Clinically unstable patient when not fit for general anesthesia

Table 10.2 Complications and Risks associated with Spinal Needle Aspiration/Biopsy

Pneumothorax
Spinal cord/Cauda equina injury

Vascular injury
Carotid/Vertebral/Aortic/intercostal artery dissection
  Pseudoaneurysm formation
  Uncontrolled bleed
  Distal thromboembolism

Severe pain due to pleural/peritoneal injury
Inappropriate needle placement Hematomyelia Spinal extradural or intradural hematoma Injury to exiting nerve roots (Neuropraxia) Injury to the sympathetic chain
Technical failure Sampling wrong level / side / person Inadequate tissue sampling Biopsy system failure
Anesthesia-related Respiratory depression Aspiration Airway compromise Anaphylactic reactions

should be discussed along with the risk-benefit analysis. The emergency systems to effectively handle the sudden cardiac arrest and the anaphylactic shock should be ensured to be intact. Urgent blood availability should also be preemptively ensured in case of uncontrolled hemorrhage requiring blood transfusions. The neurosurgery team should be kept informed for the backup of emergency laminectomy in case of hematoma within the spinal canal or hematomyelia.

10.4 Procedural Details

The accuracy of the image-guided percutaneous biopsy for providing the definitive diagnosis ranges from 74–92% depending upon the variations in the imaging modality used for guidance, hardware, and technical protocols [11]. The Biopsy scores over FNAC in the tissue sample yield available for analysis hence avoiding unnecessary repetitions, at the cost of the procedural safety, due to the more invasive nature of the involved hardware and techniques. Availability of trained manpower and advanced laboratory facilities, including the GeneXpert polymerase chain reaction test (sensitivity of 95.6% and specificity of 96.2% for spinal TB), are necessary for a seamless workflow and outcome [12].

10.5 Instrumentation

A variety of needles are available for the safe and accurate practice of spinal FNAC and Biopsy.

FNA Needles Commonly, 20 to 22 gauge needles are used with variable bevel angles (spinal—30°; Chiba—25°; Meditech, Boston Scientific, Natick, MA; Turner-45°, Cook, Bloomington, IN). The beveled edges provide a sharp cutting end for tissue penetration and increase the cross-sectional area for aspiration. Greene (Cook, Bloomington, IN), E-2-Em (E-2-EM, Westbury, NY), Crown (Meditech, Boston Scientific, Natick, MA), and Franseen (Meditech) are the aspiration cutting needles that increase the yield of the tissue with variable tip configurations [13]. They can also act as adjuvant access for coaxial biopsy systems in addition to providing extra material for microbiological analysis. Comparatively, smaller dimensions of the needles scores over the biopsy hardware in terms of safety, ease of access and patient compliance throughout the procedure and thereafter.

Biopsy Needles Automated cutting needles: ASAP, Meditech, Boston Scientific, Natick, NY; MaxCore, CR Bard, Covington, GA Trephine needle system: Craig (10-gauge, Becton Dickinson, Rutherford, NJ) and the Ackerman (12-gauge, Cook, Bloomington, IN) trephine needles.

Trephine needle systems have a large outer cannula with a fitted obturator, which is advanced to the bone surface. Trephine needle devices for subsequent FNA and cutting needle biopsies may be used as a coaxial device. FNA and cutting needles will be progressed through the outer cannula into the medullary cavity through the bone biopsy defect until the trephine needle has crossed the cortex during a core biopsy. Serial FNA and biopsies for cutting may be done. The Elson (Cook, Bloomington, IN) and Geremia (Cook, Bloomington, IN) coaxial systems use a 22-gauge needle with a removable stylet and hub to serve as a coaxial guiding the biopsy needle subsequently.

Combination Needles These have an outer hollow cutting needle and an inner trocar-boring needle. (Jamshidi, Manan Medical Products, Northbrook, IL; Ostycut, CR Bard, Covington, GA; Osteosite Cook, Bloomington, IN), thus combining the advantages of both the cutting needle & the trephine.

10.5.1 MRI-Compatible Needles

MRI-compatible FNA (18- to 22-gauge, E2-EM, Westbury, NY) and core (Comatex, Berlin, Germany Biogun, E-2-EM, Westbury, NY; Daum, Schwerin, Germany) biopsy systems can be used under MR-imaging guidance without radiation risks.

Pregnant and pediatric patients and the previously failed procedures with small lesions can be benefitted from superior soft tissue resolution and lesion delineation [14].

10.5.2 Robotically Driven FNAC/Biopsy

The newer, robotically driven artificial intelligence-based hardware advances for the CT-guided FNAC can enhance precision and safety without the radiation hazards to the operator [15]. However, the loss of tactile feedback, especially with a suboptimally cooperative patient, sophisticated infrastructure and higher cost-related setbacks are shortcomings of the robotic systems.

10.6 Aseptic and Safety Precautions

Diligent and proper hand wash with copious soap and disinfection before the procedure has no replacement. Use of disposable gown, cap and masks and sterile gloves without contaminating any of the useful surfaces as a planned step-by-step protocol, preferably in front of an observer is the best way to avoid chances of contamination (Fig. 10.1). Centrifugal dermal painting around the skin entry site with betadine and draping the surrounding unsterile parts, taking care of the smooth table movements in CT or fluoroscopy are important.

Preemptive intubation in the earmarked area as per the extant institutional infectious disease (e.g., Covid-19) protocols in a dyspneic patient to avoid emergency intubation and related aerosolization risk is the best approach. Non-intubated patients in the author's institute are made to wear a double mask with inner N-95

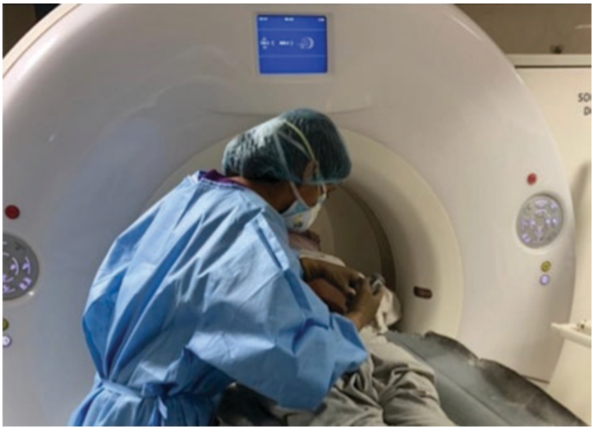

Fig. 10.1 Strict aseptic precautions with full protection need to be followed while performing the aspiration/ biopsy procedure

type and an outer surgical mask. If MRI-guided procedures are being performed, metallic content masks are avoided to prevent focal burns around the nose. Donning and doffing with strict personal protection equipment (PPE) protocols are to be followed, especially in patients harboring highly infectious disease (e.g., Covid positive).

10.7 Positioning and Needle Access

The cervical spine lesions can be accessed in both prone and supine positions depending on the location. A trans-oral approach with a secured open-mouth for the CVJ lesions and transpharyngeal access to upper cervical segments are also described. For the thoracic spine lesions, the patient is usually in a prone position with a pillow under the neck and arms by the side or above the head to suit the comfort of the patient for a posterolateral, transpedicular, or transcostovertebral approach. Many a time, letting the patients hold the cranial edge of the table with flexed elbows allows them to be comfortable motionless [16]. Lumbo-sacral lesions are usually targeted from posterior aspects after adjusting for the curvature of deformities if any, with pillows making it perpendicular to the expected needle path. Sometimes, the patient may also be in a lateral or oblique decubitus position to cater to the painful spinal deformities and obtain a motionless setup and maximum patient comfort [17]. The sacral lesions can be targeted by a posterior, perineal, or endorectal approach based on the lesion [18].

In the dorsal spine, the transcostovertebral approach offers safer, faster, and more reliable access due to easy visualization of the costovertebral joint on the axial CT images and stable positioning of the access hardware for coaxial passes [19]. The coaxial system consisting of initial access with a thinner needle and using it as a guide for insertion of the actual thicker trocar over the initial needle makes it safer and reliable for an effective yield of the tissue sample [20]. A tram-track technique of CT-guided biopsy has also been described, which involves placing a thin 23-25G spinal needle transcutaneously until the periosteum for initial marking of the access route [21]. The bone biopsy needle is subsequently introduced parallel to the spinal needle just by its side and further introduced into the bone. Choice of skin penetration site, depth, and angle of needle advancement should be decided once the patient assumes a comfortable position. Marking the skin entry after pin-pointing with laser pointers of CT gantry (Fig. 10.2), adhering to the careful progress of the needle tip with meticulous image guidance at every step is crucial. Maintaining the precise angle and depth of the needle during aspiration and biopsy maneuvers are also equally important. The patient should be adequately counseled about the importance of avoiding inadvertent body movements at all the steps.

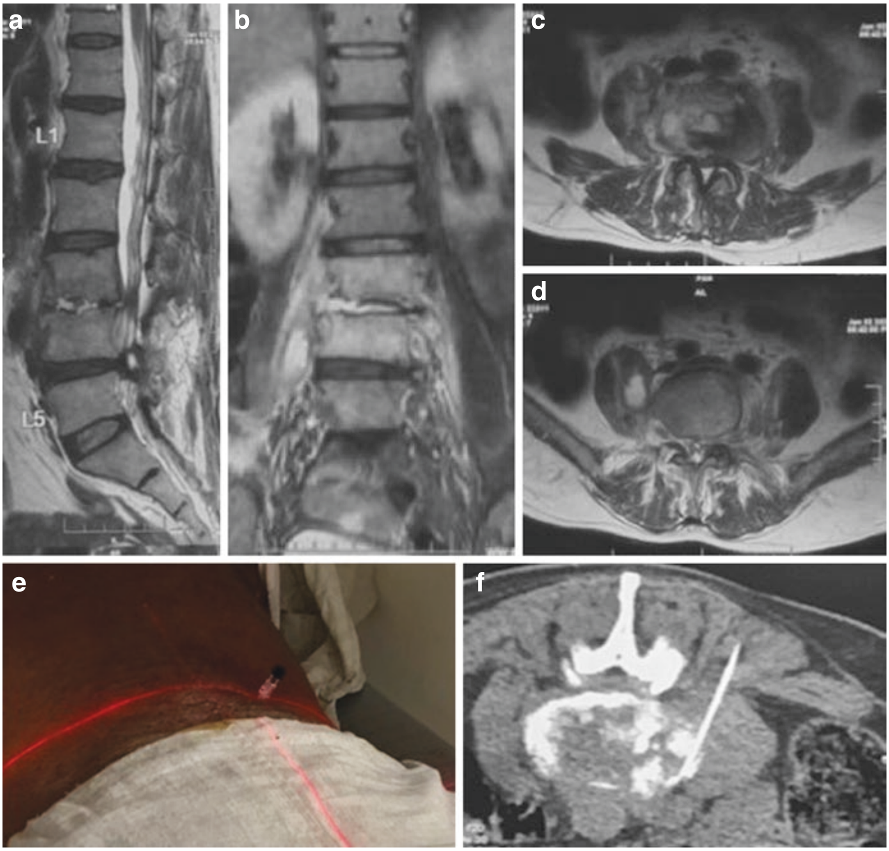

Fig. 10.2 Sagittal T2 (**a**), coronal T2 fat saturated (**b**) and axial T2 (**c**, **d**) weighted MR images demonstrating spondylodiscitis involving the L3 and L4 vertebral bodies with associated right psoas abscess. Patient lying prone on CT table with needle in situ (**e**) precisely guided and confirmed by the red laser pointers. Needle in situ evident on the CT image (**f**)

10.8 Methods of Image Guidance

Although an intact cortex of the bone restricts penetration of the ultrasound waves, the destructive lesions of spinal tuberculosis, especially in the cervicodorsal segments, readily allow the usage of sonographic guidance for needle biopsies (Fig. 10.3). Apart from the thinner subcutaneous tissue planes in these regions, continuous real-time visualization of the needle penetration up to the target tissue offers more advantages for a seamless procedure [22]. CT-guided procedures are usually the commonest amongst the FNAC/Biopsy. Most of the procedures are performed in the prone position (Figs. 10.2, 10.3, 10.4, 10.5 and 10.6). However, different

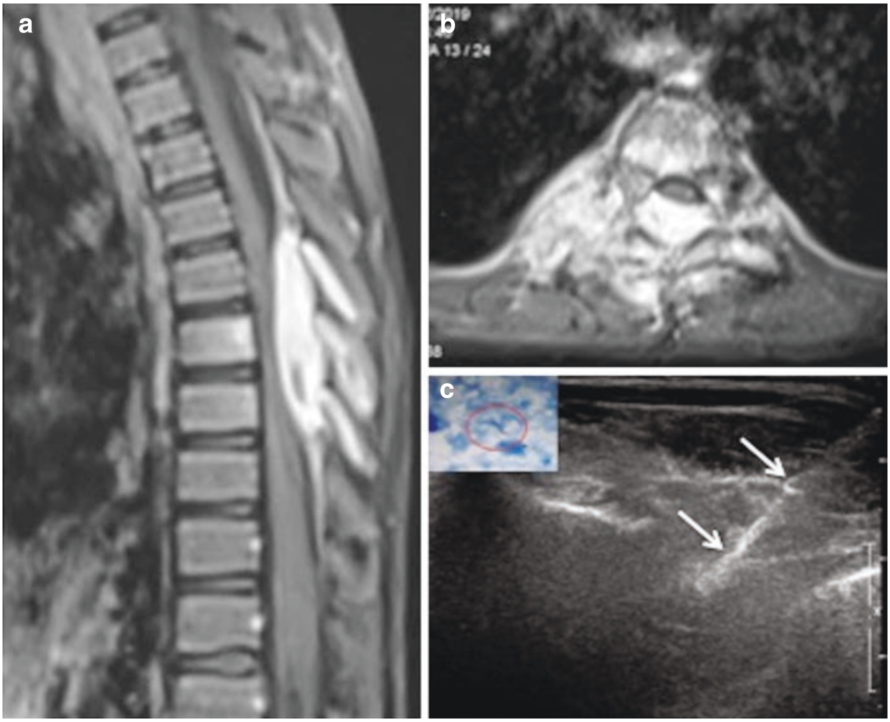

Fig. 10.3 Ultrasound-guided fine needle aspiration of tuberculous inflammatory lesion centered at the posterior arch elements of the dorsal vertebrae with contiguous involvement at three spinal levels with associated paravertebral and intraspinal extradural soft tissue component evident on sagittal (**a**) and axial (**b**) post-contrast T1 weighted MR images. Needle in situ (arrows) targeting the lesion. Acid fast bacilli evident on the aspirate slide in Fig. C (inset)

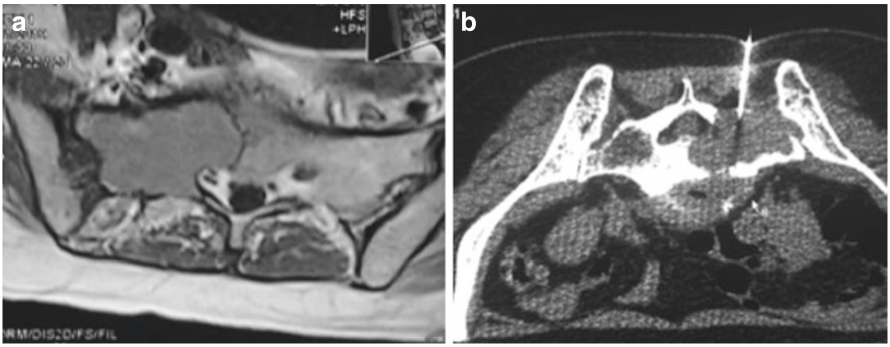

Fig. 10.4 Axial T1 weighted MRI (**a**) reveals a bone lesion in the right sacral ala. CT-guided fine needle aspiration (**b**) with the patient in prone position. The needle easily punctures the thin residual enveloping bone along the posterior aspect

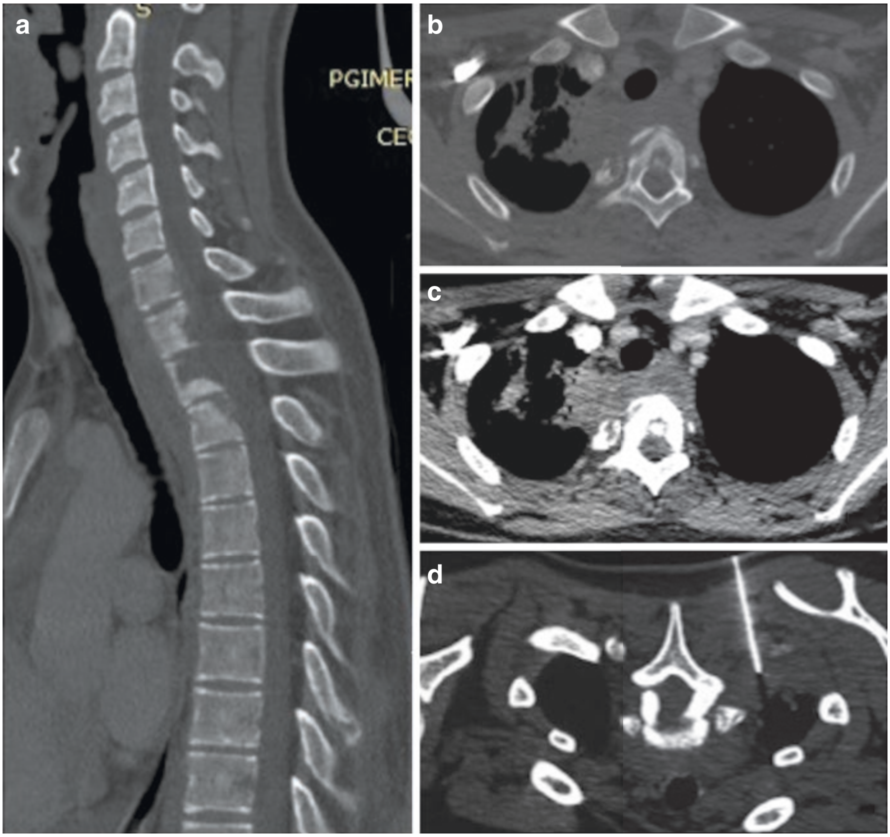

Fig. 10.5 Sagittal (**a**) and axial (**b**) CT bone window images showing lytic destructive lesion involving the vertebral bodies at D1 to D3 levels. Extensive associated soft tissue is seen on axial CT (**c**) mediastinal window section. Presence of soft tissue makes aspiration of the lesion (**d**) safe as the needle need not be directed to the vertebral body and surrounding neurovascular structures. Cytopathology revealed granulomatous lesion

convenient positions may be chosen depending on which area of the vertebra needs to be targeted. The laser pointer helps in accurately targeting the skin surface and helps to significantly reduce the navigation errors (Fig. 10.2). The following approaches are described [23] for various vertebral biopsy sites:

1. Transpedicular approach—It can be employed at any spinal level, however is most suitable for lumbar vertebral biopsy (Fig. 10.6).
2. Posterolateral extrapedicular approach—It is preferred for lumbar vertebrae where when the transpedicular approach is not feasible.
3. Superior costotransverse approach—It is the technique of choice, if feasible, for mid and lower thoracic vertebrae. The vertebral lesion is approached through superior costotransverse joint space.

Fig. 10.6 Fluoroscopically guided transpedicular approach for a lumbar vertebral body lesion

4. Inferior costotransverse approach—This is employed in upper thoracic vertebral biopsy in which the needle is introduced through the inferior costotransverse joint space.
5. Pedicular biopsy—It is done for lesions of the pedicle when the vertebral body is collapsed.
6. Anterolateral or lateral approach—It is chosen for cervical vertebra biopsy with the patient in supine position. The operator has to be careful about the key neurovascular structures in these approaches.

Presence of soft tissue helps in reducing complications as the needle may be directed away from the central spinal and neurovascular structures (Fig. 10.5). Lesions with significant bony destruction may actually be easily targeted. The thin intact cortex can be easily breached with some pressure applied on the fine needle during its introduction at the directed target (Fig. 10.4). Choosing the low dose protocols (like the manual reduction of the kV to around 80–90) or use of dedicated-based biopsy protocols helps to avoid artifacts as well as reduce radiation exposure. Covering only the limited area of interest and providing radiation protection to the patient (like lead goggles, lead shields around the genitals) can also reduce inadvertent exposure. MRI guidance for the needle biopsy should be done with an entirely MRI-compatible kit after the screening of the patient as per the MRI-safety protocols as well as Gadolinium-based contrast safety requirements. Preferably, a lower gradient strength magnet (1.5 Tesla or lower) should be chosen, and faster gradient T1-based sequences are used for tissue localization.

Fluoroscopic guidance is also commonly used for dorsolumbar lesions (Fig. 10.6) by attaining "bull's eye view of the pedicle" from the anteroposterior plane providing direct transpedicular access [11]. CT-fluoroscopy can also be used in case the lesion is closer to the aorta or major vessels, and appropriate confirmation of the needle tip position can be done with selective angiograms. Fusion imaging guidance with CT-fluoroscopy and matched sections of the contrast-enhanced MRI becomes helpful in cases with difficult access with unsuccessful prior attempts.

10.9 Radiation Exposure and Prevention

The risk of radiation hazards in the CT/fluoroscopically guided needle biopsy is negligible owing to the short procedure time. However, the repetitive procedures with difficult access and lack of operator experience may add to the radiation time and dose. The operator must observe strict radiation protection for the self and the entire team. Lead aprons, thyroid shield, lead goggles, if possible, lead gloves should be used while performing CT/fluoroscopic guidance. Portable lead shields and separators are also effective in warding off the scattered radiation. Iterative reconstruction and the newer artificial intelligence-based advances in post-processing of the CT images can be applied for the reduction of needle artifacts.

10.10 Conclusion

FNAC/Biopsy in spinal TB is an important part of the management, providing timely definitive diagnostic decisions and avoiding inadvertent delay and failure of therapy. Image-guided needle aspiration or biopsy is best practiced as a team effort with no communication gaps, consisting of radiologist, spine surgeon, neurologist, and pathologist. Detailed pre-procedural assessment of clinical and imaging features with clear delineation of target tissue with contrast-enhanced MRI and apt planning of the required hardware and image guidance modality are a sine-qua-non. Ensuring optimal patient positioning, adequate anesthesia, pain management with strict radiation safety protocols and post-procedural care are important adjuvants of the procedure. CT forms the dominant image-guided modality to secure access for spinal aspirations. Ultrasound and MRI guidance can be alternative options in pregnant and pediatric patients with radiation hazard-related concerns. Fusion imaging with advanced robotic systems can be useful aids in apt set up for safe and precise needle access without radiation to the operator.

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