Lumbar Spine Biopsy

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Learning Objectives

1. To learn the pertinent radiologic anatomy, including bony, neural, and vascular anatomy, as it relates to image-guided lumbar spine biopsy
2. To review the most common indications and contraindications for image-guided lumbar spine biopsy
3. To review different approaches and techniques when planning image-guided coaxial lumbar spine biopsy

6.1 Introduction

Of all the image-guided percutaneous spine biopsy procedures that are performed along the spinal axis, lumbar spine biopsy is the most frequently performed of these procedures.

Compared to the cervical spine, percutaneous biopsy of the lumbar spine is relatively safer and technically less difficult. The thicker lumbar pedicles and larger surface area for initial needle insertion allow ease of navigation around adjacent critical nerves and vasculature. Numerous pathologic entities, including infectious and neoplastic processes, can originate from or spread to the lumbar spine and paraspinal tissues. A study of 410 biopsied lumbar spine lesions found metastatic breast and lung cancer to be the most common etiologies found in women (28% and 7%, respectively), while metastatic lung and prostate cancer were found to be the predominant etiologies in men (12% and 7%, respectively) (Lis et al. 2004). Image-guided percutaneous lumbar spine biopsy is generally useful, as the vast majority of procedures yield an adequate specimen for diagnosis (Kornblum et al. 1998). Due to the variety of pathologies affecting the lumbar spine, the diagnostic yield of a biopsy sample varies depending upon the cause of disease as well as on the internal architecture of the lesion. Lumbar spine biopsy for primary and metastatic tumors has an accuracy of approximately 90%. The reported accuracy of spine biopsy for infection is less accurate, only providing a diagnosis around 50% of attempted biopsies (Hau et al. 2002). In spite of the high rate of sample adequacy, the most frequent adverse outcome remains nondiagnostic sampling, especially for the evaluation of spine infection. Image-guided percutaneous lumbar spine biopsy possesses the lowest rate of diagnostic utility in lesions that contain a large necrotic component, diffuse vascularity, or are densely blastic (Sundaresan et al. 2004; Wu et al. 2008). Sclerotic lesions present a particular challenge compared to their lytic counterparts due to the technical difficulty denser tissue presents when extracting a sample. In addition, clinical scenarios in which the likelihood of neoplastic or infectious pathology is low, but there is an overlap in the imaging findings between neoplastic and degenerative pathologic processes or between infectious and inflammatory

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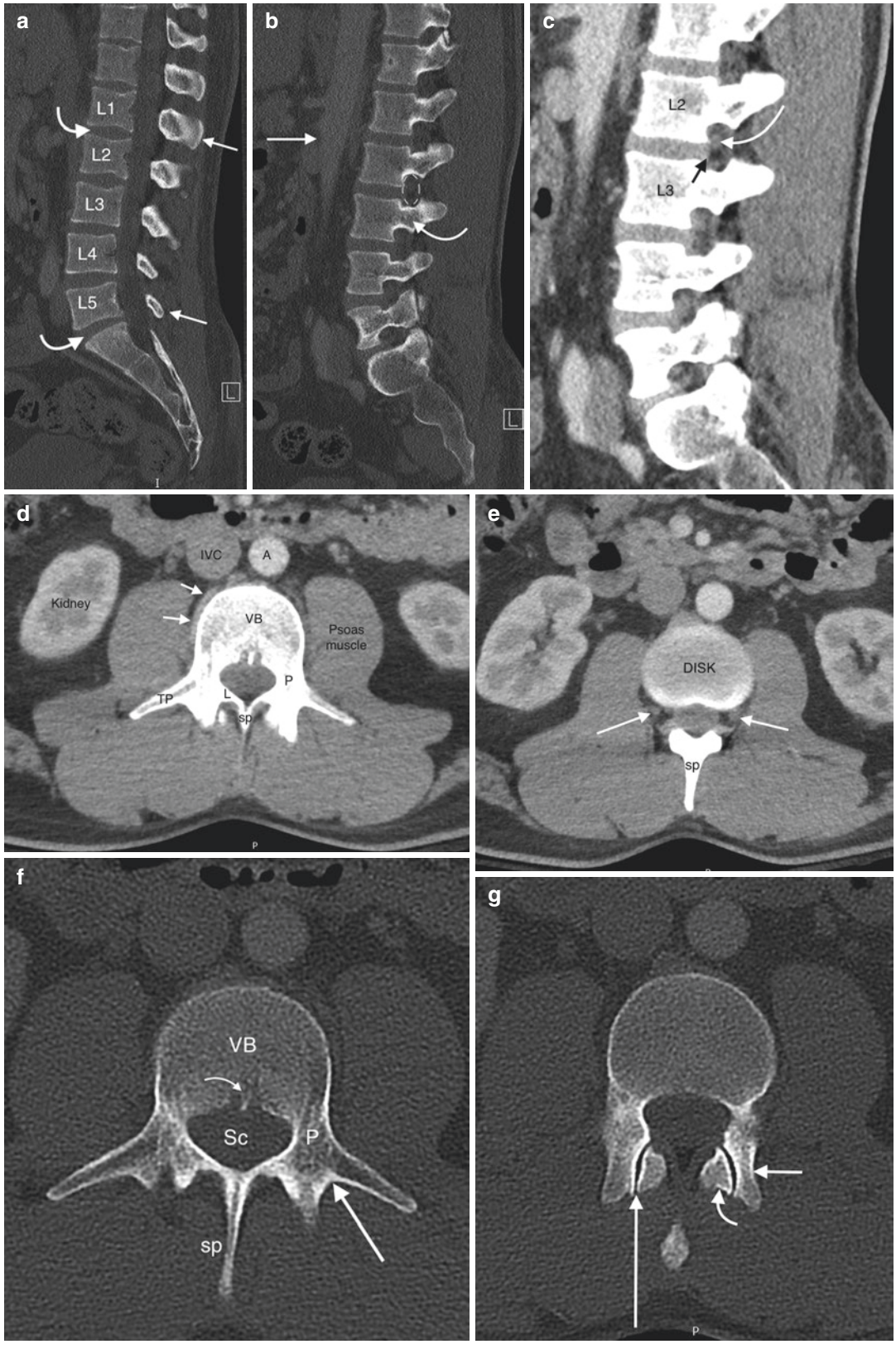
or traumatic processes, raise the suspicion for neoplasm or infection just enough that a biopsy is requested. For example, in an older patient, the presence of extensive degenerative changes of the spine, and a concomitant diagnosis of metastatic disease, may lead to a false suspicion of sclerotic metastases (Ghelman et al. 1991). For similar reasons, differentiating pathologic from benign osteoporotic compression fractures in an elderly patient population presents an ongoing challenge to clinicians.

Over the past several decades, due to a combination of progressive advancements in radiology imaging equipment, image-guiding technology as well as the instruments for performing these procedures, image-guided percutaneous biopsy techniques have grown in use and utility. Despite open biopsy remaining the ultimate procedure for diagnosis, percutaneous spine biopsy has become the preferred method at most institutions around the world (Hau et al. 2002). CT- and fluoroscopic-guided biopsy provides numerous advantages over open biopsy, the most notable of which is a lower morbidity (Chooi et al. 2007). Percutaneous access affords numerous benefits over open surgical techniques, including lower rates of postoperative wound infection, a lower incidence of post-biopsy pathologic fracture, and avoidance of complications from general anesthesia (Schajowicz and Derqui 1968; Murphy 1983). Furthermore, image-guided spine biopsy serves as a cost-effective diagnostic tool, due to the shorter procedure time compared with open techniques and the shorter post-procedure recovery time (Schajowicz and Derqui 1968; Murphy 1983; Peh 2006). Post-biopsy observation varies by institution, but, generally, lasts no longer than 3 h, whereas open techniques may require an overnight hospital stay (Lis et al. 2004). Percutaneous lumbar spine biopsy is an invaluable tool in establishing a diagnosis and guiding subsequent disease-specific treatment. This chapter aims to elucidate the various techniques of fluoroscopic- and CT-guided lumbar spine biopsy as well as provide an overview of different indications and complications that the operator should consider prior to performing the procedure.

6.2 Anatomic Considerations

The lumbar spine typically consists of five lumbar vertebrae and their intervening intervertebral disks (Fig. 6.1). Although biopsy at the level of the lumbar spine is often technically less demanding compared to other locations in the spine, it remains crucial to consider the anatomical structures surrounding the lumbar vertebrae and intervertebral

Fig. 6.1 CT anatomy of the lumbar spine. Midline reformatted sagittal CT image (**a**) in bone window algorithm shows five lumbar vertebral bodies (*L1–L5*) and their corresponding spinous processes (*arrows*) and the intervertebral disks (*curved arrows*); note the orientation of the most caudal disk space (*lower curved arrow*). Reformatted left parasagittal CT image (**b**) in bone window algorithm shows the vertebral pedicle (*curved arrow*) and its relationship to the posterior vertebral body and to the neural foramen (dashed oval); the aorta is partially visualized (*arrow*). Close-up of same image (**c**) in soft tissue algorithm shows the *L2* dorsal root ganglion (*curved arrow*) within the neural foramen at the *L2–L3* level; the proximity of posterior disk (*arrow*) to the nerve is also noted. Contrast-enhanced axial CT image (**d**) in soft tissue algorithm shows the vertebral body (*VB*), pedicle (*P*), transverse process (*TP*), lamina (*L*), and spinous process (*sp*). The erector spinae and multifidus muscles lie posterior to the posterior elements, and the psoas muscle lies lateral to the vertebral body. The lumbar artery (*arrows*) is segmentally visualized along the midpole of the vertebral body. The aorta (*A*) and inferior vena cava (*IVC*) lie anterior to the vertebral body, and the kidneys are seen laterally. The bowel is seen anterior to the aorta and inferior vena cava. Contrast-enhanced axial CT image (**e**) in soft tissue algorithm at the level of the intervertebral disk shows the dorsal root ganglia (*arrows*) and the base of the spinous process (*sp*). Axial CT image (**f**) in bone window algorithm shows the trabecular structure of the vertebral body (*VB*) and a small central focal defect within the posterior vertebral body cortex that corresponds to the basivertebral plexus (*curved arrow*). The spinal canal (*Sc*) is bordered anteriorly by the posterior vertebral cortex, laterally by the pedicles and posteriorly by the laminae. The laminae join to support the spinous process (*sp*). The posterior surface of the pedicle (*arrow*) lies medial to the transverse process and is the access point for a transpedicular approach. Axial CT image (**g**) in bone window algorithm at the level of an upper lumbar facet joint (*large arrow*) shows the more lateral superior articular facet (*small arrow*) that corresponds to the vertebra shown and the more medial inferior articular facet (*curved arrow*) of the vertebra above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disks. Image-guided percutaneous lumbar spine biopsies are almost universally performed from a posterior approach. The operator must guide the needle through the posterior paraspinal musculature including the erector spinae and multifidus or quadratus lumborum muscles, in order to access the vertebral body and/or paravertebral soft tissues. Often a transpedicular approach is selected for access to a vertebral body lesion as the pedicle size within the lumbar vertebra can easily accommodate most commercially available biopsy needle systems. Access via the pedicle, if possible, can serve as a safe conduit into the vertebral body (Chooi et al. 2007). Care must be taken to ensure that the medial border of the pedicle is not breached prior to entering the posterior vertebral body in order to avoid inadvertent entrance into the spinal canal. Although the location of the needle tip must be monitored during a transpedicular approach, there is reduced risk to adjacent soft tissues, nerves, or vasculature once the needle passes within the safe channel provided by the pedicle. An alternate approach for biopsy, however, may be necessary depending upon the location of the lesion within the vertebral body. For example, smaller posterior median lesions may not be accessible via a transpedicular route. The intervertebral disk and the paraspinal soft tissues, likewise, are usually not accessed via a transpedicular approach. Posterolateral or extrapedicular approaches are optional trajectories, and an active awareness of the anatomic location of neural and vascular structures is critical toward reducing the risk of injury with these approaches. The lumbar arteries arise from the aorta and run along the equatorial or midportion of the vertebral body, coursing posteriorly, where they enter the neural foramina bilaterally. These arteries give rise to both vertebral nutrient arteries which supply blood to the vertebrae and radiculomedullary arteries which can contribute to the blood supply of the spinal cord and cauda equina. Visualization of these vessels is often difficult during lumbar spine biopsy, especially since the procedure is performed without the use of intravascular contrast agents when using imaging guidance. It is nevertheless important to consider and be aware of these vascular structures when using a posterolateral approach.

Often a transpedicular approach is selected for access to a vertebral body lesion as the pedicle size within the lumbar vertebra can easily accommodate most commercially available biopsy needle systems.

The spinal cord terminates as the conus medullaris usually at the L1–L2 level of the spinal canal. This critical structure must be accounted for when considering lumbar spine biopsy procedures within the upper lumbar spine. The cauda equina, a constellation of sensory and motor nerve roots, arises from the conus medullaris. These nerve roots are named for the vertebra bordering the superior portion of the neural foramen through which they pass (e.g., the L2–L3 neural foramen contains the L2 nerve root). These nerves enter the proximal neural foramina bilaterally above the level of the disk space at their respective intervertebral level and course along the superior portion of the foramen. As the nerve roots exit the foramen, they course inferiorly. The L1–L4 nerve roots join to form the lumbar plexus which runs along and within the psoas musculature. The operator must consider the location of the nerve roots when performing a posterolateral approach. These approaches are frequently performed with CT guidance and therefore allow direct but segmental visualization of the nerve with respect to needle trajectory.

CT guidance can offer more direct visualization of anatomic structures related to the lumbar spine which may be particularly helpful when using a posterolateral approach.

The aorta runs along the anterior margin of the lumbar spine, almost always on the left side; the inferior vena cava is located on the right side (Fig. 6.1). A lesion may occasionally extend to and penetrate the anterior cortex of the vertebral body. Identification of the lesion's extension with respect to the aorta and inferior vena cava is important in preventing potential injury to these

vital structures. Injury to the aorta is rare, as most lesions are confined to the vertebral bodies. It may be appropriate to utilize CT guidance in these cases to ensure proper visualization of the aorta and inferior vena cava in relation to the biopsy needle. If fluoroscopic guidance is considered, the use of lateral imaging is necessary during advancement of the biopsy needle to prevent penetration of the anterior cortex of the vertebral body or the anterior aspect of the intervertebral disk. The lumbar sympathetic plexus is located bilaterally along the anterior and lateral aspect of the lumbar vertebral column. Fortunately, no significant injuries to this structure with lumbar spine biopsy have been reported. The other critical organs, however remote, that must always be considered when performing lumbar spine biopsy include the inferior aspects of the lungs and pleura, the kidneys, and the bowel.

Once a request for percutaneous image-guided lumbar spine biopsy has been received, all available and pertinent imaging studies must be reviewed and a planned needle trajectory formulated bearing in mind the aforementioned anatomic structures. Consideration of needle approach will be required to ensure proper sampling of the lesion within the vertebral body, intervertebral disk, or paraspinal soft tissue. All approaches rely on a careful review of the available imaging examinations and the assessment of anatomic structures, lesion location, and lesion size in order to ensure that the optimal needle trajectory is chosen.

Knowledge of the critical anatomy of the lumbar spine is extremely important in planning needle trajectory for image-guided percutaneous lumbar spine biopsy and for avoiding complications.

6.3 Indications

Image-guided percutaneous biopsy of the lumbar spine allows access to the vertebral body, posterior elements, intervertebral disks, as well as surrounding soft tissues. Requests for lumbar spine biopsies are most frequently a result of imaging (i.e., CT, MRI, PET-CT, bone scan) that shows the possible presence of a neoplastic or infectious process (Peh 2003; Hodge 1997). A list of most common indications for image-guided percutaneous lumbar spine biopsy is provided in Table 6.1. Histopathologic identification of malignancy plays an important role in the management of newly diagnosed malignancy, modification of current treatment, and assessment of prognosis in metastatic disease of a known primary malignancy (Sundaresan et al. 2004; Herkowitz and Wesolowski 1986). In particular, tissue identification of specific etiologies of malignancy may change oncologic management – a patient previously planned for surgery may be discovered to have a plasmacytoma or lymphoma involving the spinal canal and thus would benefit from other treatments such as chemotherapy or radiation. Even after treatment, patients many times require lumbar biopsy to exclude disease recurrence when a new lesion is identified on an imaging study (Peh 2003; Hodge 1997). More recent advances in medical therapy have reinforced the importance of biopsy, such as evaluating active lesions demonstrated on PET imaging. Emerging concepts such as tailoring specific treatment regimens to the inherent

Table 6.1 Indications for image-guided percutaneous lumbar spine biopsy

1. Infection
Spondylitis-diskitis
Paraspinal abscess
2. Neoplasm
Primary osseous neoplasm
Evaluation of solitary bone lesion
Secondary osseous neoplasm
Osseous metastatic disease or involvement by systemic malignancy
Diffuse marrow replacement process
Evaluation of neoplastic lesions with diffusion restriction or FDG-PET avidity posttreatment to assess for treatment response
Paraspinal soft tissue mass
Pathologic vertebral body compression fracture
3. Pretreatment (including the above categories)
Tissue characterization prior to treatment initiation

biologic heterogeneity of a neoplasm requires biopsy for accurate tissue sampling and subsequent genetic analysis (Talac and Mclain 2009).

Lumbar spine biopsy may be requested in patients who were initially considered to have benign disease, but subsequent clinical evaluation suggests otherwise. For example, in patients with back pain secondary to what is initially thought to be an osteoporotic vertebral compression fracture, when symptoms worsen or concerning imaging characteristics such as progressive tumor growth or pathologic abnormality emerge, tissue sampling may be beneficial to exclude malignancy (Herkowitz and Wesolowski 1986). Additionally, equivocal imaging findings or patient anxiety from uncertainty may result in a request for image-guided biopsy. Another common indication for lumbar spine biopsy is for definitive diagnosis of vertebral osteomyelitis and/or diskitis (Peh 2003; Hodge 1997; Herkowitz and Wesolowski 1986). Occasionally, the clinical presentation raises suspicion for spinal infection, which can be confirmed with MR imaging of the spine. In this setting, lumbar spine biopsy plays an important role in identification of the infectious organism, which enables antimicrobial therapy to be tailored specific to the infectious pathogen. Alternatively, both imaging and clinical findings may not be specific for spinal infection, which then requires biopsy with surgical pathology evaluation of core tissue from the disk and/or vertebral body for diagnostic confirmation or exclusion.

6.4 Contraindications

Image-guided percutaneous lumbar spine biopsy is a relatively safe procedure with few contraindications (Table 6.2). A major contraindication, however, is uncorrected coagulopathy (Santiago et al. 2014). This is often the result of anticoagulant therapy, but may also be seen in patients who have intrinsic coagulopathy due to underlying malignancy or other disease states. When possible, it is important to hold anticoagulation therapy prior to procedure to reduce risk of hemorrhage (refer to the Chap. 2). Consultation with the provider managing this therapy is often necessary to ensure that holding this medication does not produce additional risk to the patient due to a thromboembolic event. In patients with intrinsic coagulopathy, it may be necessary to infuse platelets or administer vitamin K prior to the procedure, such as when platelet counts fall below 50,000/mcL (Peh 2006). Again, the operator should discuss the appropriate management of the coagulopathy with the responsible patient care provider(s). Occasionally, consultation with a hematologist may provide additional insight into the appropriate management.

Table 6.2 Contraindications to image-guided percutaneous lumbar spine biopsy

Absolute
Uncorrected coagulopathy
Untreated infection in patient with suspicious mass lesion
Relative
Patient factors
Combative or uncooperative patient
Clinically unstable patient
Lesion type
Vascular lesion
Probable benign lesion
Lesion size
Discretion must be exercised with smaller lesions (< 5 mm in diameter)
Limited or no specimen yield may result in false negative biopsy
Lesion location
Defer biopsy for lesions located adjacent to critical structures or inaccessible locations

Preexisting infection at the skin site, such as a cellulitis or a decubitus ulcer, can sometimes occur near the intended area for possible percutaneous biopsy. Infection at the skin site or within the soft tissues surrounding a tumor can be considered a contraindication to percutaneous biopsy (Peh 2003; Hodge 1997; Ghelman 1998). Although unlikely, the spread of the infection into deep soft tissues, tumor, or within the vertebral body can occur if a soft tissue infection, such as a cellulitis, is not treated prior to biopsy. Consultation with an infectious disease specialist may be necessary to optimize antibiotic therapy and provide medical clearance prior to biopsy.

Patients who are uncooperative or unstable are not candidates for image-guided lumbar spine biopsy (Peh 2006). If a patient is clinically unstable, it is prudent to wait until the patient is medically stabilized as well as to consult with the patient's clinical providers in order to assess for the urgency and clinical need for a biopsy. With respect to uncooperative patients, after discussion with the appropriate patient representative and requesting provider, a clinically necessary lumbar spine biopsy can be performed under general anesthesia or monitored anesthesia care. The risk and benefits of the anesthesia and the need for tissue diagnosis must be carefully assessed in order to appropriately triage candidates for the procedure. The type of lesion may also influence whether or not a biopsy gets performed. Hypervascular lesions may dissuade an operator for fear of a hemorrhagic event. The operator should try to avoid performing biopsy procedures in cases where the radiographic features are highly suggestive or pathognomonic of a benign lesion (Figs. 6.2 and 6.3). Very small (less than 5 mm diameter) lesions may not be amenable to biopsy; it just may not be possible to obtain tissue. Lesions, especially small lesions, that are located near critical structures such as the spinal cord, lung, or aorta may also not be amenable to percutaneous biopsy.

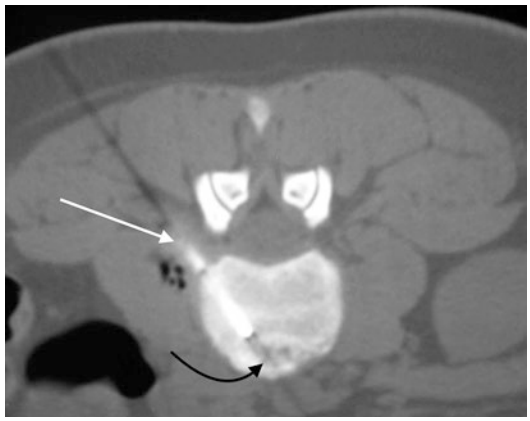


Fig. 6.2 Axial CT image shows posterolateral approach with bone biopsy needle (*arrow*) for biopsy of a round sclerotic lesion with a lucent center at the vertebral endplate. This is a Schmorl's node and a biopsy was not necessary

6.5 Risks and Complications Associated with Lumbar Spine Biopsy and How to Minimize Them

It is important for the operator to be aware of the potential complications that have been associated with lumbar spine biopsy in order to help reduce the overall risk to the patient during this procedure (Ortiz et al. 2010) (Table 6.3). Complications from image-guided percutaneous lumbar spine biopsy are relatively uncommon, with a reported rate of less than 1–3% (Tehranzadeh et al. 2007). Although image-guided lumbar spine biopsy is safely performed on a routine basis, operators must be aware of potential complications in order to first prevent and avoid them and, second, to acutely manage such situations in order to avoid further injury to the patient. Lumbar spine biopsy complications can be divided into acute and delayed or late complications (Tehranzadeh et al. 2007). Acute complications after lumbar spine biopsy include subcutaneous hemorrhage or hematoma formation, hemorrhage from biopsy of hypervascular lesions, neurologic injury, dural puncture, and vertebral fracture. Specifically, renal cell carcinoma and thyroid carcinoma are well-known examples of hypervascular tumors that are prone to hemorrhage when biopsied (Talac and McLain 2009). An acute or even subacute complication that is often overlooked by operators is the occurrence of a thromboembolic event (myocardial ischemia in a patient with coronary artery stents or stroke in a patient with atrial fibrillation) in a patient when anticoagulant or antiplatelet medication has been transiently discontinued. Late complications, which can arise weeks to months after the spine biopsy procedure, include infection and tumor seeding along the needle tract. Risk of infection is low in the setting of percutaneous biopsy when performed with appropriate sterile preparation of the biopsy entry/access site. In one study, no postprocedural infections were reported out of 94 CT-guided spine biopsy cases (Olscamp et al. 1997). Needle tract seeding by tumor is also a late complication and is rare when utilizing specific coaxial techniques and the smaller gauge

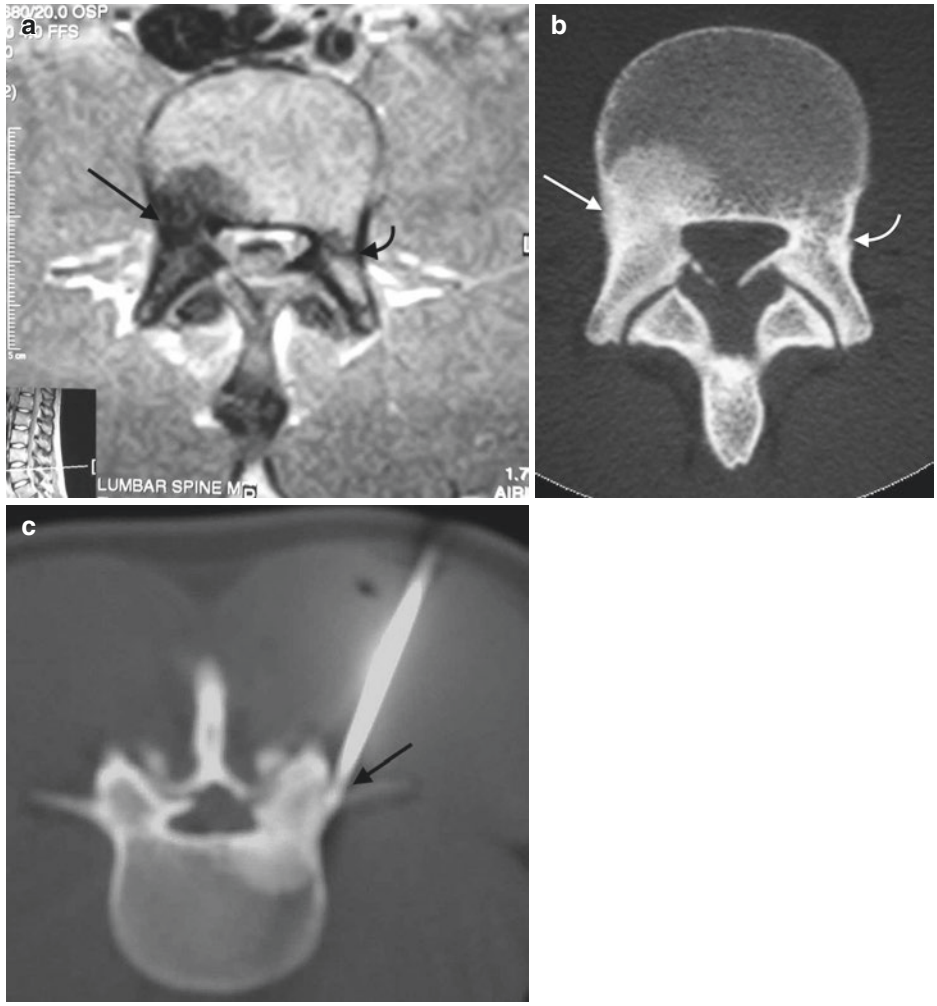


Fig. 6.3 A 20-year-old male with chronic low back pain. T1-weighted axial image (**a**) shows a hypointense lesion within the pedicle (*arrow*) and a linear hypointense defect within the opposite pedicle (*curved arrow*). The clinicians and family insisted upon a biopsy procedure for what is obviously a stress fracture. Axial CT image (**b**) in bone window algorithm shows sclerosis in the right pedicle (*arrow*) and a fracture line (*curved arrow*) in the left pedicle. Axial CT image (**c**) shows biopsy of the sclerotic pedicle with a bone needle (*arrow*). The biopsy was negative

needle sizes that are typically used for spine biopsy (Saghieh et al. 2010; Davies et al. 1993).

Hemorrhage can occur with any invasive procedure, and a minimal amount is often unavoidable. Therefore, correction of coagulopathy is important to help reduce the risk of significant hemorrhage during lumbar spine biopsy. As previously mentioned, a coaxial approach minimizes the need for multiple passes through the skin, subcutaneous soft tissues, and muscles when accessing the vertebral body or paravertebral soft tissues. Reduced manipulation of the adjacent soft tissue results in reduced risk of injury to vascular structures. In the lumbar spine, the lumbar arteries typically pass along the equatorial plane of the vertebral body and traverse the anterior margin of the neural foramen to enter the posterior vertebral body as the nutrient supply to the vertebral body (Fig. 6.1). Although there are multiple periosteal arteries that originate along the course of the lumbar artery, it is not usually necessary to identify these vessels since access into the vertebral body is transpedicular or parapedicular, avoiding injury to these vascular structures.

Table 6.3 Percutaneous lumbar spine biopsy: potential risks and complications

Tissue injury
Vascular injury
Neural injury
Pneumothorax
Hemorrhage Superficial or subcutaneous Deep – hemorrhage into a tumor and/or spinal canal can result in acute neurologic changes, or retroperitoneal hemorrhage can result in hypotension or severe pain
Infection (superficial or deep) in those cases being performed to assess for neoplasm
Inappropriate needle placement Breach of the anterior vertebral body or medial pedicle cortex Needle placement within the spinal canal Wrong level
Inadequate tissue sampling
Technical failure – biopsy system failure, lost specimen
Tumor seeding along the biopsy tract
Radiation exposure
Anesthesia complications Aspiration, airway compromise, respiratory depression
Thromboembolic events in patients with reversed anticoagulation/antiplatelet therapy

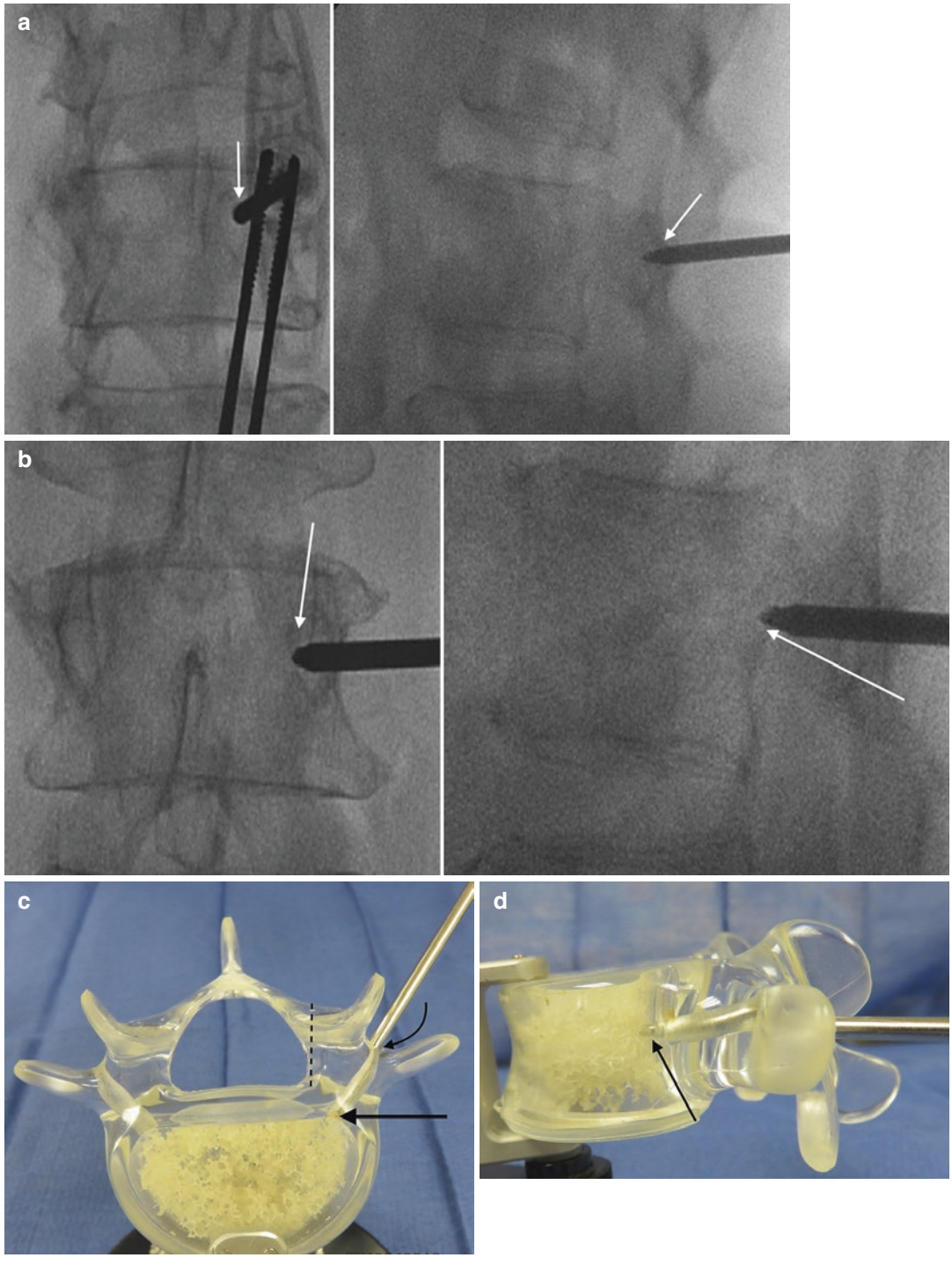
Biopsy of hypervascular tumors can result in excessive bleeding. Typically, waiting 5–10 min with the stylet placed in the introducer needle when using a coaxial needle system will result in hemostasis. Occasionally, it may be necessary to inject Gelfoam or Surgifoam into the introducer needle along the biopsy tract to achieve hemostasis (Talac and McLain 2009). The use of a smaller needle in these types of lesions also can reduce the risk of hemorrhage. An alternative to core needle biopsy of suspected hypervascular lesions is fine-needle aspiration. This technique allows for the placement of a small needle, typically 25 or 27 gauge, and can often yield enough cellular tissue to establish a histologic diagnosis.

Injury to the lumbar nerve roots, as well as the thecal sac (dura mater), can be avoided with the use of CT guidance. Visualization of these structures in relation to the advancing needle tip can allow the operator to modify needle trajectory or establish a new path of needle placement if there is concern for injury to neural structures. It is important to be able to identify important bony landmarks when performing spine biopsy under fluoroscopic guidance as direct visualization of neural structures is not possible with this imaging modality. Specifically, when using a transpedicular approach, it is necessary to ensure that the biopsy needle does not penetrate the medial margin of the pedicle as seen on the anterior-posterior fluoroscopic projection prior to reaching the posterior margin of the vertebral body as seen on the simultaneous lateral fluoroscopic projection. Confirmation of this precise needle positioning will ensure that the needle does not penetrate the medial border of the pedicle and advances into the spinal canal (Fig. 6.4).

6.6 Imaging Guidance

The most commonly utilized modalities for image-guided percutaneous lumbar spine biopsies are CT, CT fluoroscopy, and fluoroscopy. A meta-analysis of 25 studies revealed accuracy rates of 90.2% and 88.1% for CT- and fluoroscopic-guided biopsies, respectively, when compared to the subsequent clinical confirmation of the diagnosis (Nourbakhsh et al. 2008). The use of other modalities, such as MRI and ultrasound, is limited in the setting of lumbar spine biopsies. It is often challenging to use MRI for imaging guidance due to limited scanner availability, procedure time, and the need for specialized MRI-compatible biopsy equipment. Additionally, patients with certain types of implants (e.g., certain aneurysm clips and non-MRI conditional pacemakers) cannot be placed in MR scanners. Ultrasound can be used for superficial soft tissue biopsy or aspiration of subcutaneous fluid collections, but cannot be reliably utilized for deep bone lesions due to the significant shadowing that occurs with cortical bone.

CT guidance is often the preferred modality for sampling discrete lesions in lumbar spine biopsy (Fig. 6.5). It provides visualization of important anatomic structures, excellent spatial resolution, and the ability to help guide the biopsy needle into small focal lesions within the vertebral body (Lis et al. 2004; Peh 2006; Ortiz et al.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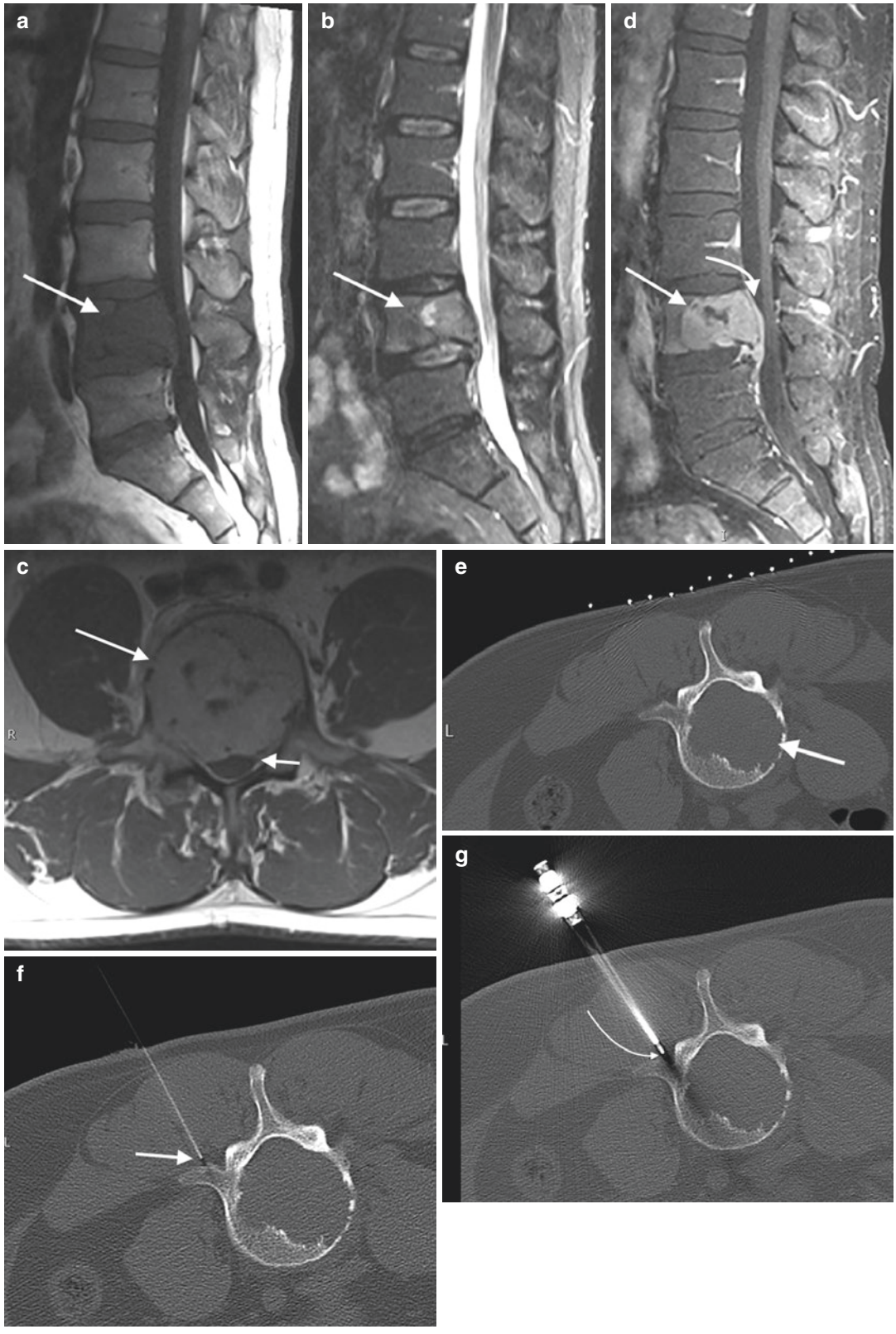
2010). The operator can obtain images at multiple time points throughout the procedure in order to guide the biopsy needle into the desired location while simultaneously evaluating the needle position relative to critical organs and vascular and neural structures. Imaging confirmation of biopsy needle placement within the lesion will document that the appropriate abnormality was sampled in the event that a "nondiagnostic" pathology result is obtained. This can be seen on occasion with lesions treated with prior radiation, cystic lesions, and necrotic lesions. The CT gantry can also be angled to parallel the area of interest, such as the disk space or vertebral body, to allow visualization of a possible or actual needle path in a single plane (Fig. 6.6). Some CT fluoroscopy systems enable the operator to obtain axial and sagittal reconstructions during needle advancement. Moreover, for lesions where resection may eventually be performed, including resection of the biopsy tract, CT better documents the path of the biopsy needle and the skin entry point for the surgeon to later follow when resecting residual tumor (Lis et al. 2004).

Although radiation is required for CT and fluoroscopic procedures, the operator can employ lower-dose techniques to reduce radiation dose to the patient without affecting diagnostic yield (Shpilberg et al. 2014). Strategies that can be used to reduce the patient's radiation exposure during a spine biopsy procedure include reviewing the prior studies to optimize the procedure before you perform it, limiting the scan volume to the area of interest (e.g., focusing on two or three vertebral levels instead of the entire lumbar spine), adjusting CT scanner parameters such as tube current modulation (mAs) and tube potential (kV) based upon patient and body part size, and using automatic exposure control features of the CT scanner and radiation dose monitoring. CT fluoroscopy also reduces procedure time by allowing sequential imaging of needle placement while the operator remains in the procedural suite. Typically, after the operator presses a foot pedal, a set of three images are obtained, which include an image below, at, and above the level of imaging. The operator can use this information to modify trajectory in order to ensure appropriate needle placement into the vertebral lesion. Although radiation exposure through this technique is reduced for the patient, it is important for the operator to be actively aware of their own radiation exposure during these procedures. Modern CT fluoroscopy scanners typically have a leaded area along the outside of the scanner which allows for minimal operator exposure when scanning. Alternatively, the operator can stand behind a portable lead shield a short distance away from the gantry; this exploits the benefit of the inverse square law for reducing radiation exposure to the operator and the benefit of added radiation shielding.

Fluoroscopic guidance can be employed in the setting of more diffuse vertebral body disease and suspected spinal infections. This modality allows real-time imaging of needle placement and advancement into the vertebral body or disk space (Pierot and Boulin 1999). Some major

Fig. 6.4 Initial needle positioning for the transpedicular approach. Oblique and lateral fluoroscopic images (**a**) obtained simultaneously with a bone needle docked on the posterior surface of the pedicle (*arrows*). The oblique orientation shows the needle tip within the "eye of the Scotty dog" (*arrow*). Frontal and lateral fluoroscopic images (**b**) obtained simultaneously show advancement of the bone needle through the pedicle to the margin of the posterior vertebral body as shown on the lateral image (*arrow*). It is very important to observe that the needle tip has not crossed the medial pedicle cortex (*arrow*) as shown on the frontal projection (if it had, then the needle tip would be in the spinal canal!). A photograph of a plastic see-through vertebral body model (**c**) from an overhead view with a bone needle (*curved arrow*) inserted to the same position as in (**b**) shows the tip of the needle (*large arrow*) at the junction of the anterior pedicle and posterior vertebral body. Note that the needle tip has not crossed the medial pedicle cortex (*dashed arrow*); compare to the frontal fluoroscopic image in **b**. A photograph of the model from a lateral view (**d**) with the needle in the same position shows the needle tip at the pedicle-vertebral body junction (*arrow*); compare to the lateral fluoroscopic image in **b**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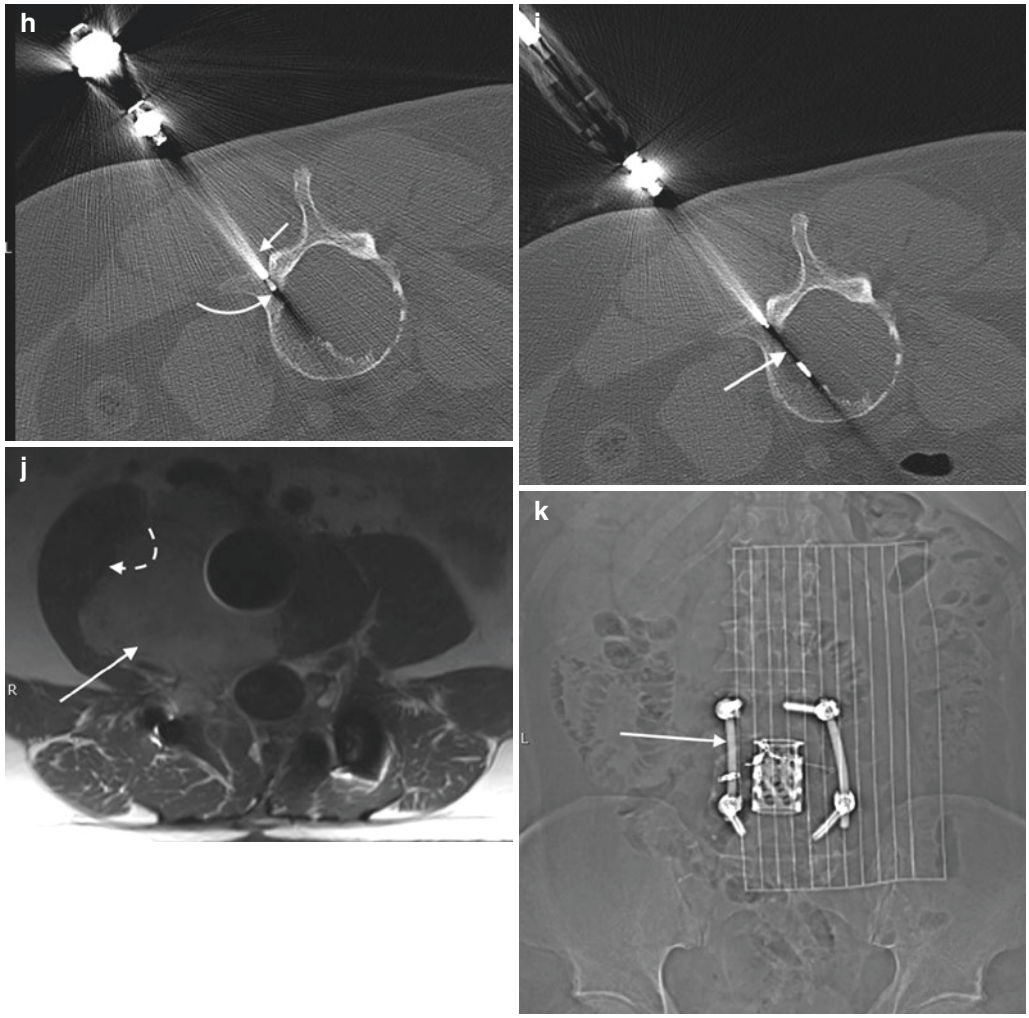
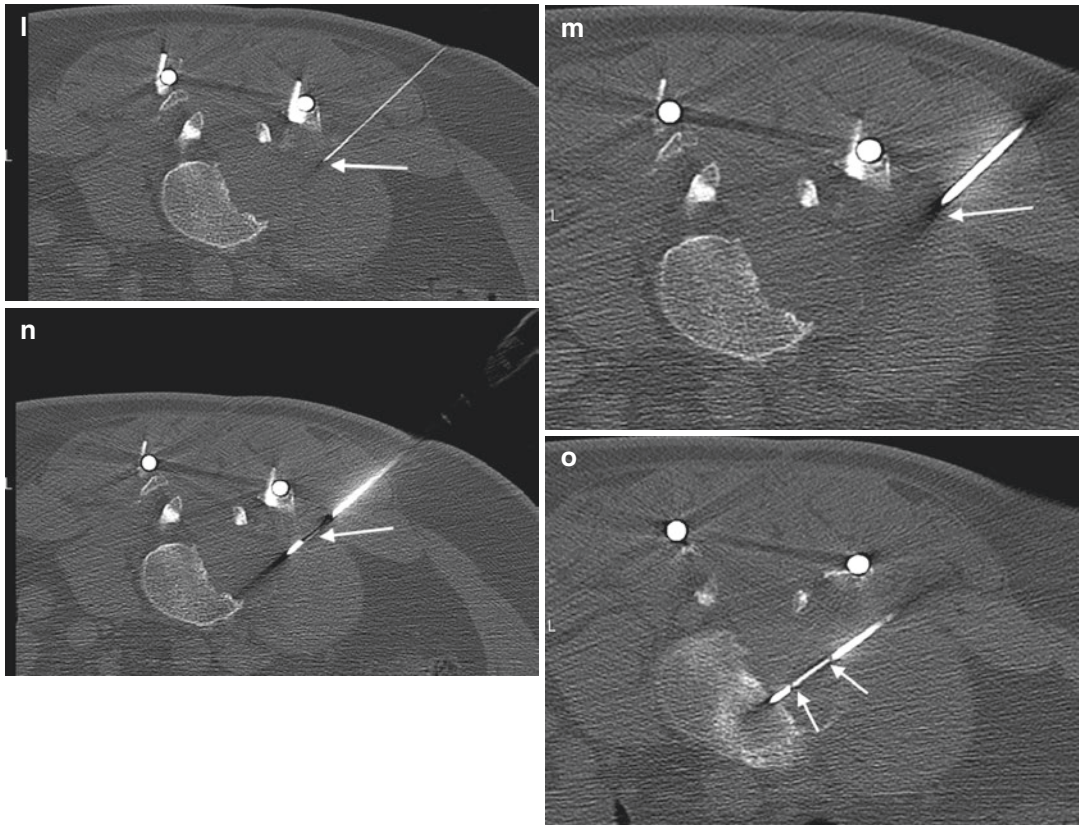


Fig. 6.5 (continued)

Fig. 6.5 A 47-year-old male with low back pain. T1-weighted sagittal image (**a**) shows a hypointense lesion within the L4 vertebral body; the lesion has a thin hypointense anterior margin (*arrow*). T2-weighted sagittal image (**b**) shows a moderately hyperintense lesion (*arrow*) that encroaches upon the spinal canal. Contrast-enhanced T1-weighted axial image (**c**) shows a diffusely enhancing lesion (*large arrow*) with ventral epidural encroachment (*small arrow*). The fat-suppressed contrast-enhanced T1-weighted sagittal image (**d**) better delineates the mass (*arrow*) and shows the epidural encroachment (*curved arrow*). Axial CT image (**e**) during the spine biopsy procedure shows a large lytic vertebral body lesion (*arrow*). Axial CT image (**f**) shows a spinal needle (*arrow*) that is used to infiltrate the posterior pedicle with local anesthetic. Axial CT image (**g**) shows a coaxial bone biopsy needle system docked (*arrow*) into the posterior pedicle cortex. Axial CT image (**h**) shows advancement of the bone needle (*curved arrow*) through the pedicle with the guide cannula (*arrow*) in place. Axial CT image (**i**) shows coaxial placement of a cutting needle (*arrow*) through the guide cannula; this was possible once the initial bone needle pass created an access channel to the lytic lesion. Follow-up contrast-enhanced T1-weighted axial image (**j**) obtained 1 year after L4 corpectomy and anterior and posterior fusion; the patient is asymptomatic. A solid moderately enhancing mass (*arrow*) displaces the psoas muscle laterally (*curved arrow*). Scout frontal CT image (**k**) from a biopsy procedure shows a skin grid partially overlying the area of instrumentation from L3 to L5 (*arrow*). Axial CT image (**l**) shows insert needle (*arrow*) used to anesthetize the margin of the large soft tissue mass. Axial CT image (**m**) shows coaxial advancement of a guide needle (*arrow*). Axial CT image (**n**) shows soft tissue cutting needle (*arrow*) that was inserted via coaxial technique. Axial CT image (**o**) shows sequential advancement of the biopsy needle through the lesion. The initial biopsy provided a pathologic diagnosis of giant cell tumor, and the follow-up biopsy confirmed the presence of a recurrent tumor



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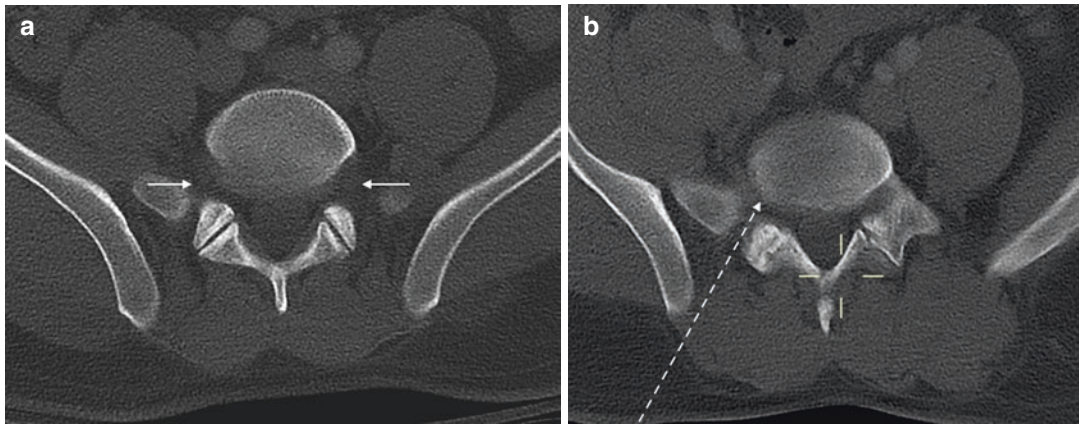


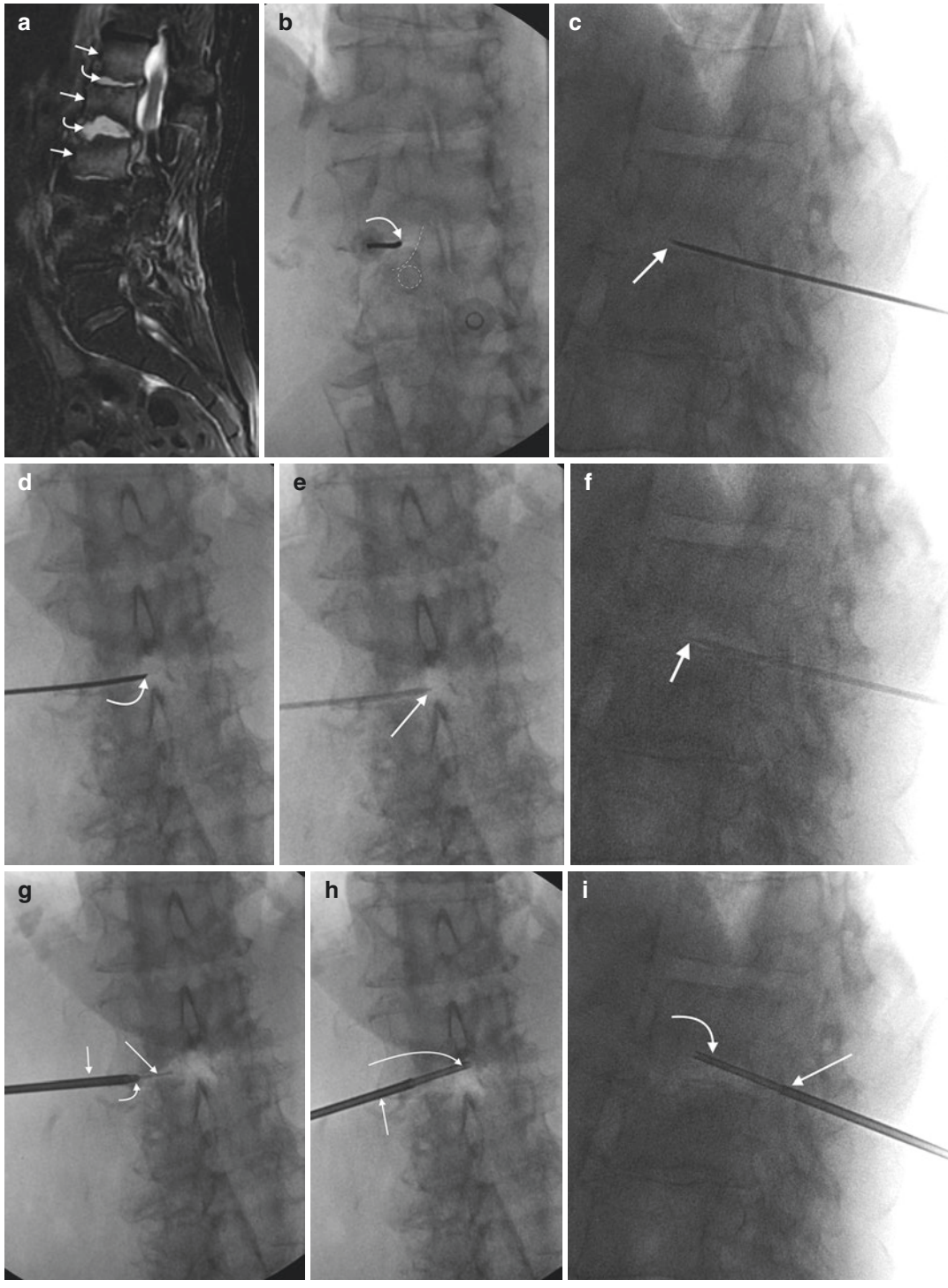
Fig. 6.6 Axial CT image (**a**) at L5–S1 shows a compromised approach to the L5–S1 disk; the dorsal root ganglia (*arrows*) essentially block access to the disk. This reformatted axial CT image (**b**) shows the effect of gantry angulation; the L5–S1 disk can now be accessed with this superomedial approach (*dashed arrow*)

advantages of fluoroscopy over CT are reduced procedure and imaging time needed to access the biopsy site, and immediate access to a procedural suite if a complication occurs (Nourbakhsh et al. 2008). Lateral fluoroscopy enables the operator to safely advance the needle into the anterior column of the vertebral body with real-time imaging. In addition, fluoroscopy can often provide quick access to the intervertebral disk space (Fig. 6.7). Some of the physical limitations of a CT scanner can be overcome by fluoroscopic imaging, such as when sampling the L5–S1 disk space and endplate complex. The steep angulation of the disk space at L5–S1 often limits access when using CT guidance, as the gantry angle is typically limited in paralleling the imaging slice to the disk space. Oblique and caudal angulation with fluoroscopy allows for appropriate visualization of the L5–S1 vertebral endplates and disk space; the greater angulation and positioning capacity of fluoroscopy provides more direct access for needle insertion into the L5–S1 disk. Identification of bony landmarks in this projection is critical for proper needle positioning in order to avoid neural structures, in particular, the exiting nerve root. Patient exposure to radiation during fluoroscopy-guided lumbar spine biopsy procedures can be reduced by utilizing appropriate fluoroscopy techniques such as low-dose pulsed fluoroscopy, automatic exposure control, collimation and last-image hold features, fluoroscopy time monitoring with alarm functions, and radiation dose monitoring. The operator's exposure to radiation during the procedure can similarly be reduced by optimizing fluoroscopy time and distance and by using appropriate shielding techniques (Luchs et al. 2005).

6.7 Approaches

As previously discussed, the transpedicular and posterolateral approaches are the two most commonly utilized approaches for image-guided percutaneous needle biopsy in the lumbar spine (Fig. 6.8). The most important factor that influences which approach to use is the lesion location within the lumbar spine. The inability to directly access the lesion via the pedicle eliminates the transpedicular approach as an option (Fig. 6.9). Typically, lesions located in the anterior or lateral margins of the vertebral body, disk space, or within paraspinal soft tissues require an extrapedicular or posterolateral approach (Pierot and Boulin 1999). This allows appropriate angulation of the needle trajectory in order to access the lesion (Fig. 6.10). We again must emphasize that it is important for the operator to be aware of the location of neural and vascular structures using this approach. CT guidance is often necessary to visualize soft tissue structures in relation to needle placement. For lesions located within the posterior elements, a biopsy of one or more of these structures may be necessary. Posterior element structures that can be successfully biopsied with CT guidance include the facet joint, the vertebral pedicle, the lamina, and the spinous process (Fig. 6.11). These are smaller structures as compared to the vertebral body; hence, CT guidance is often necessary to ensure accurate placement into these structures and to avoid complications. Often, the needle trajectory parallels the long access of the posterior element in order to allow for needle purchase into the bone and sufficient tissue sampling (Fig. 6.12). Diffuse vertebral body pathology or large focal lesions can be biopsied through a transpedicular approach if the lesion can be easily reached through the vertebral pedicle (Ashizawa et al. 1999). Transpedicular approaches can be performed with fluoroscopic or CT guidance, as bony landmarks are also clearly visible with the former modality (Fig. 6.13).

Careful pre-procedure review of available CT/MR imaging is crucial to planning a needle approach. This step is emphasized as careful planning will decrease intraoperative procedure time and complications.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6.8 The Lumbar Spine Biopsy Procedure

6.8.1 General Considerations

6.8.1.1 Patient Factors

Percutaneous lumbar spine biopsies are performed to establish or confirm a diagnosis in both healthy and ill patients. A clear clinical picture of the patient's overall mental and physical health status should be considered prior to performing a procedure. Patients who present with altered mental status and significant comorbidities may not be candidates for lumbar spine biopsy; this may require consultation with the appropriate provider to determine the need and feasibility of a safe biopsy procedure. For clinically stable, yet uncooperative patients or younger patients, it may be necessary to perform the procedure with monitored anesthesia care or general anesthesia in order to ensure that the patient remains still during the procedure. Certain patient factors such as severe pain, recent abdominal or thoracic surgery, or respiratory challenges may not allow for patients to lie in the prone position. In these circumstances, decubitus or oblique positioning may be necessary. Intravenous pain medication and sedation with appropriate patient monitoring can be helpful in order to keep the patient comfortable during the procedure.

Prior to the procedure, the operator should reconcile medications, review allergies, and check the coagulation profile, such as platelet count, prothrombin time, activated partial thromboplastin time, and international normalized ratio (INR). The patient should be NPO after midnight the evening prior to the procedure if they are receiving intravenous sedation and analgesia. Patients who have eaten before the procedure cannot receive conscious sedation, but can still be considered for the procedure if local anesthesia is determined to be sufficient for pain control. A review of the imaging and order request should also be performed to identify and document that the appropriate lumbar level and lesion are being sampled and to confirm if any additional test is required such as flow cytometry. Informed con-

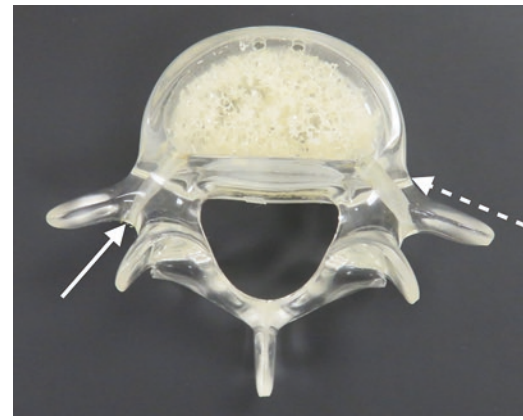


Fig. 6.8 Photograph of plastic vertebrae model shows the two basic approaches for lumbar spine biopsy, either through the pedicle (transpedicular) (*solid arrow*) or lateral to the pedicle (extrapedicular or posterolateral) (*dashed arrow*)

Fig. 6.7 An 86-year-old female with severe back pain. Fat-suppressed T2-weighted sagittal image (**a**) shows hyperintense signal within three consecutive vertebral bodies (*arrows*) and abnormal signal within the intervening disks (*curved arrows*) at T12–L1 and L1–L2. Oblique fluoroscopic image (**b**) shows advancement of a 17 gauge spinal needle (*curved arrow*) just lateral to the superior articular process (*dashed line*); the pedicle is outlined by a dashed oval. Lateral fluoroscopic image (**c**) shows advancement of the spinal needle into the center of the abnormal L1–L2 disk space (*arrow*); note the loss of the vertebral endplates at this level. Corresponding frontal fluoroscopic image (**d**) shows the needle tip within the center of the disk (*arrow*). Frontal fluoroscopic image (**e**) shows exchange of the needle stylet for a percutaneous diskectomy device (*arrow*). The lateral fluoroscopic image shows the tip of the diskectomy device within the disk (*arrow*). This device is moved in short excursions under fluoroscopic monitoring in order to extract tissue from the disk. Frontal fluoroscopic image (**g**) shows exchange of the percutaneous diskectomy system for a bone biopsy guide cannula (*small arrow*) and introducer (*curved arrow*) over a guidewire (*long arrow*). Frontal fluoroscopic image (**h**) shows that a trephine bone needle (*curved arrow*) has been advanced into the guide cannula (*arrow*) after removal of the introducer and guidewire; the bone biopsy system is angled cephalad in order to sample osseous tissue. Lateral fluoroscopic image (**i**) shows the bone biopsy needle (*curved arrow*) within the inferior L1 vertebral body; the guide cannula (*arrow*) is situated near the posterior aspect of the disk

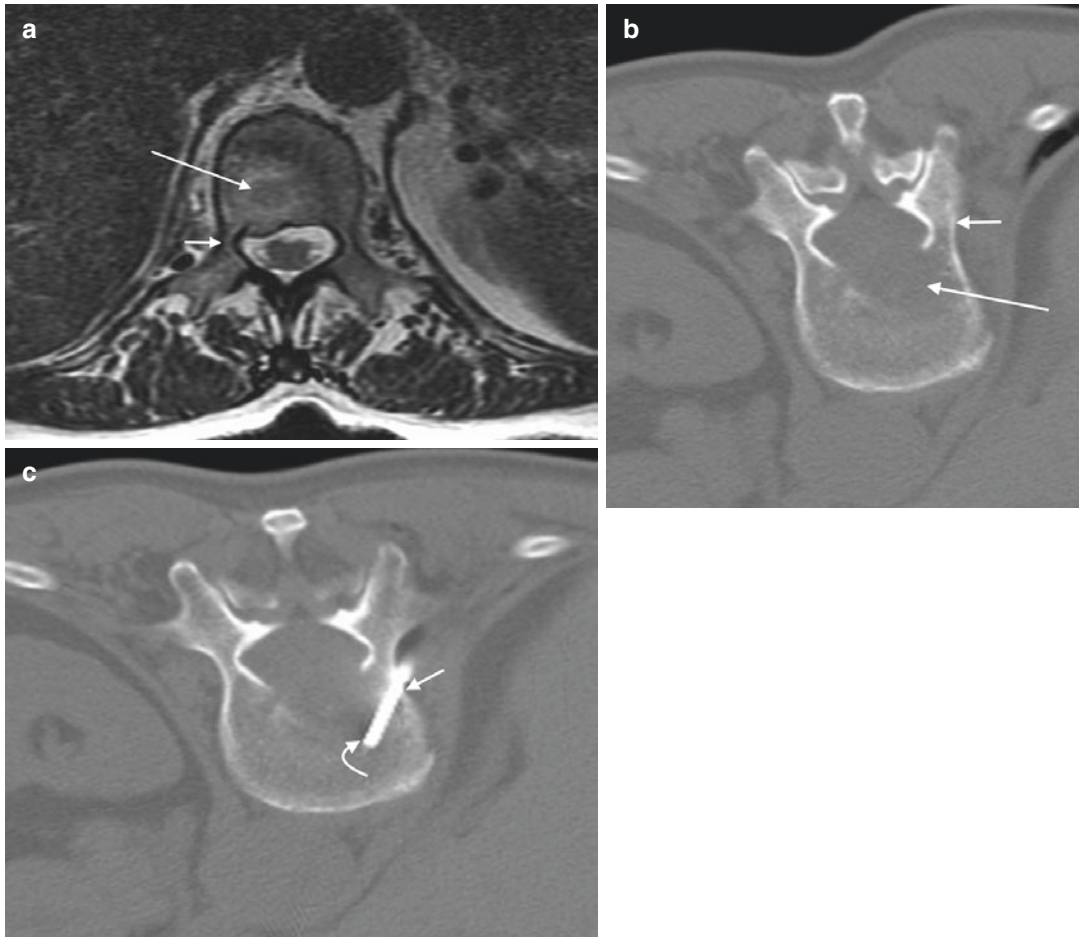
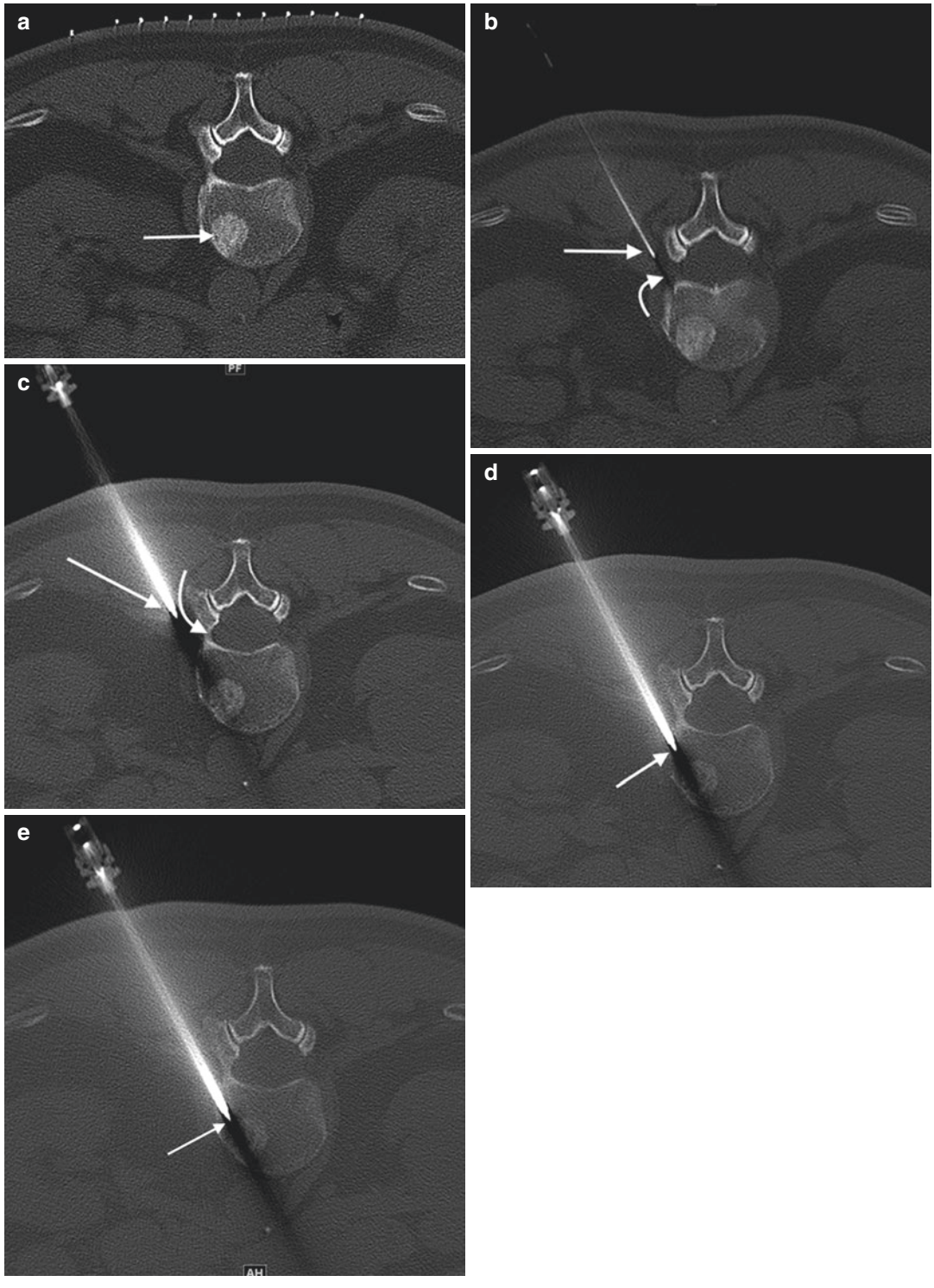


Fig. 6.9 A 77-year-old female with diffuse back pain. T2-weighted axial image (**a**) shows a focal slightly hyperintense lesion within the posterior aspect of the vertebral body (*large arrow*); the pedicles (*small arrow*) are small in size. Axial CT image (**b**) in bone window algorithm shows the posterior and paramedian location of the lytic lesion (*large arrow*); again note the small pedicles (*small arrow*). Axial CT image (**c**) shows biopsy needle (*curved arrow*) inserted into the lesion via an extrapedicular approach (arrow)

Fig. 6.10 A 65-year-old male with sclerotic L1 vertebral body lesion. Axial CT image (**a**) with skin grid in place shows a small round sclerotic lesion (*arrow*) within the L1 vertebral body. Axial CT image (**b**) shows the use of a spinal needle (*arrow*) for the injection of a local anesthetic agent. Given the proximity of the needle to the dorsal root ganglion (*curved arrow*), the trajectory of the subsequent needle placement is adjusted. Axial CT image (**c**) shows a bone needle (*arrow*) that is introduced using an extrapedicular approach. This trajectory was chosen to avoid the small pedicle (*curved arrow*) and to maximize the sampling volume of what is already a small lesion. Axial CT images (**d**, **e**) show careful advancement of the bone needle to the margin of the lesion (*arrows*). Axial CT image (**f**) shows the bone needle just beyond the distal margin of the lesion (*arrow*) and stopping just before the anterior vertebral body cortex (*curved arrow*); note the aorta (**a**). Post-procedure axial CT image (**g**) shows a lucent biopsy tract (*arrows*) through the sclerotic lesion, a pathologically proven prostate metastasis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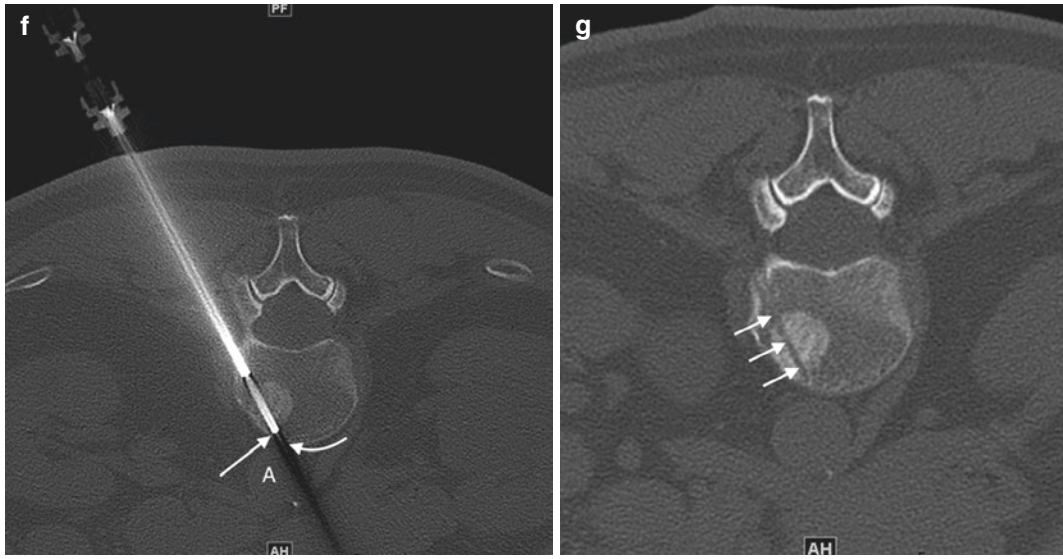

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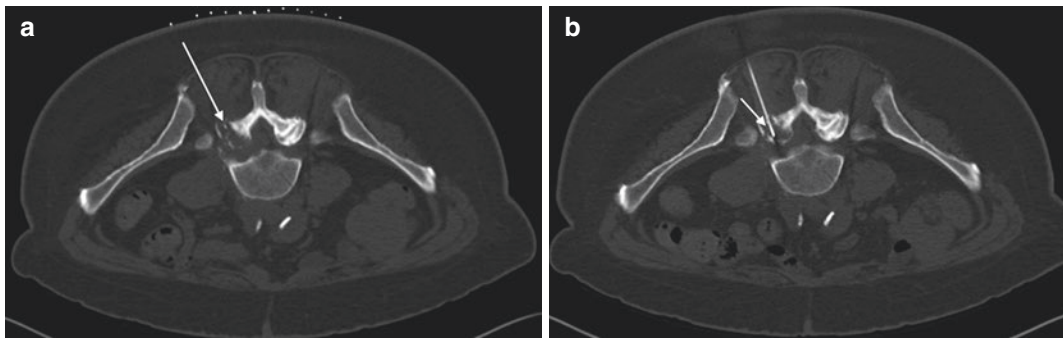
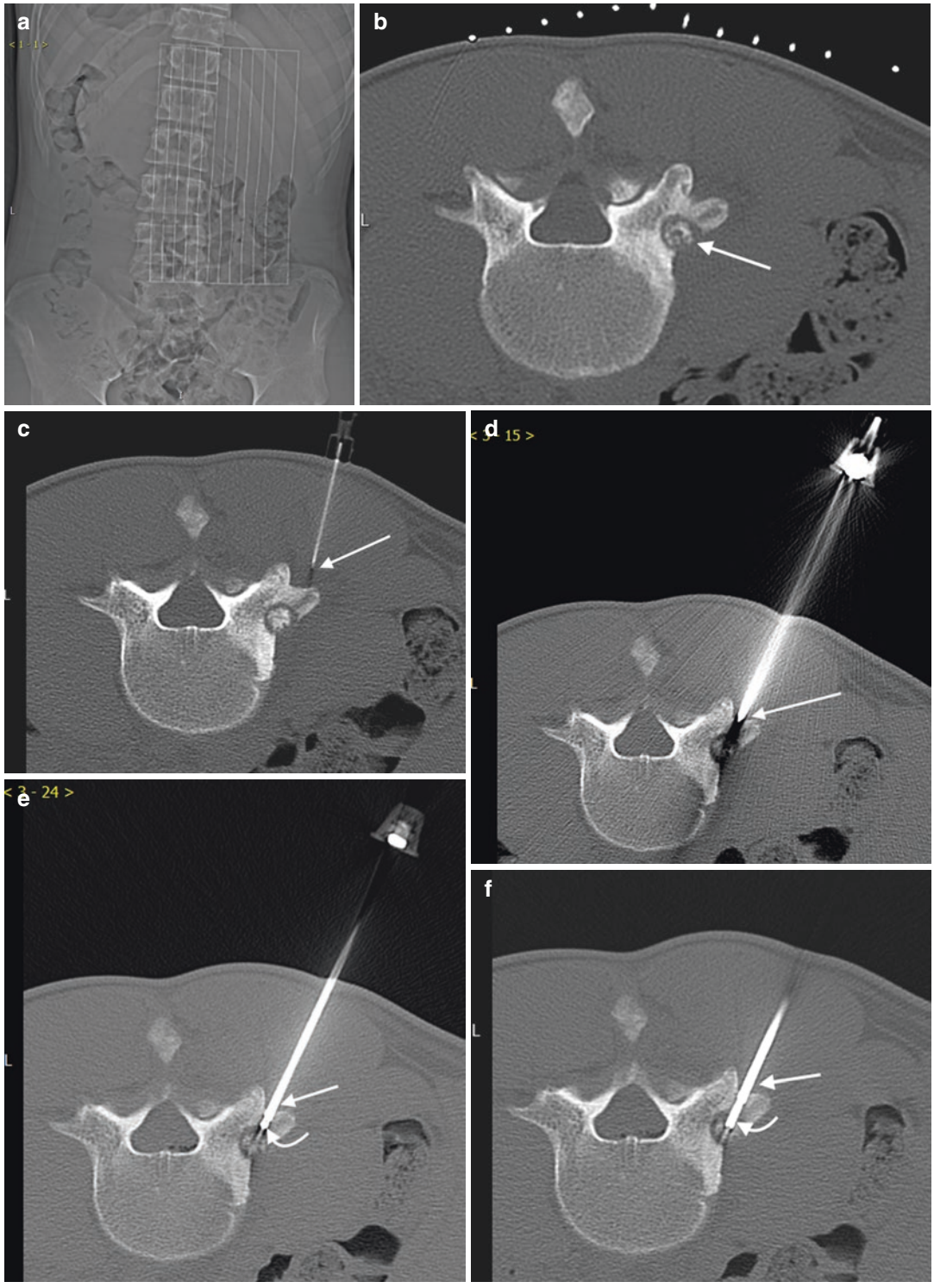


Fig. 6.11 Posterior element (facet joint) biopsy. Axial CT image (**a**) shows a destructive lesion of the left L5–S1 facet joint (*arrow*). Axial CT image (**b**) shows direct fine-needle aspiration (*arrow*) of the joint to evaluate for infection or infiltrative mass

Fig. 6.12 An 18-year-old male with chronic severe back pain, worse at night. Scout frontal radiograph (**a**) from CT scan shows skin grid in place over five lumbar vertebra and mild levoscoliosis. Axial CT image (**b**) in bone window algorithm with a skin grid in place shows a small round hypodense lesion (*arrow*) with a small sclerotic center and sclerotic reaction within the right L4 pedicle. Axial CT image (**c**) shows the use of a 22 gauge needle (*arrow*) to infiltrate the deep soft tissues and posterior pedicle cortex with a local anesthetic agent. Axial CT image (**d**) shows docking (*arrow*) of the coaxial bone biopsy system on the posterior aspect of the pedicle. Sequential axial CT images (**e**–**g**) show coaxial sequential advancement of a bone biopsy needle (*curved arrow*) through the guide cannula (*arrow*) that is docked into the posterior pedicle cortex; samples of the lesion are obtained from the lesion with each sequential advancement of the bone needle. The position and location of the bone needle is monitored with each movement. The pathologic evaluation was consistent with osteoid osteoma. This lesion was successfully treated with radiofrequency ablation immediately after the biopsy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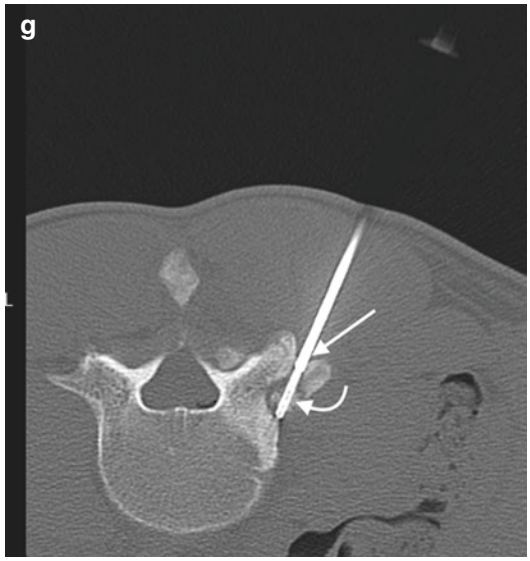


Fig. 6.12 (continued)

sent must be reviewed and signed by the patient or appropriate patient representative. The risks, benefits, and alternatives of the procedure should be discussed, including the option of open biopsy. The patient and patient representatives should have an opportunity to ask questions. Postoperative wound care should be discussed with the patient and, when necessary, the designated caretaker.

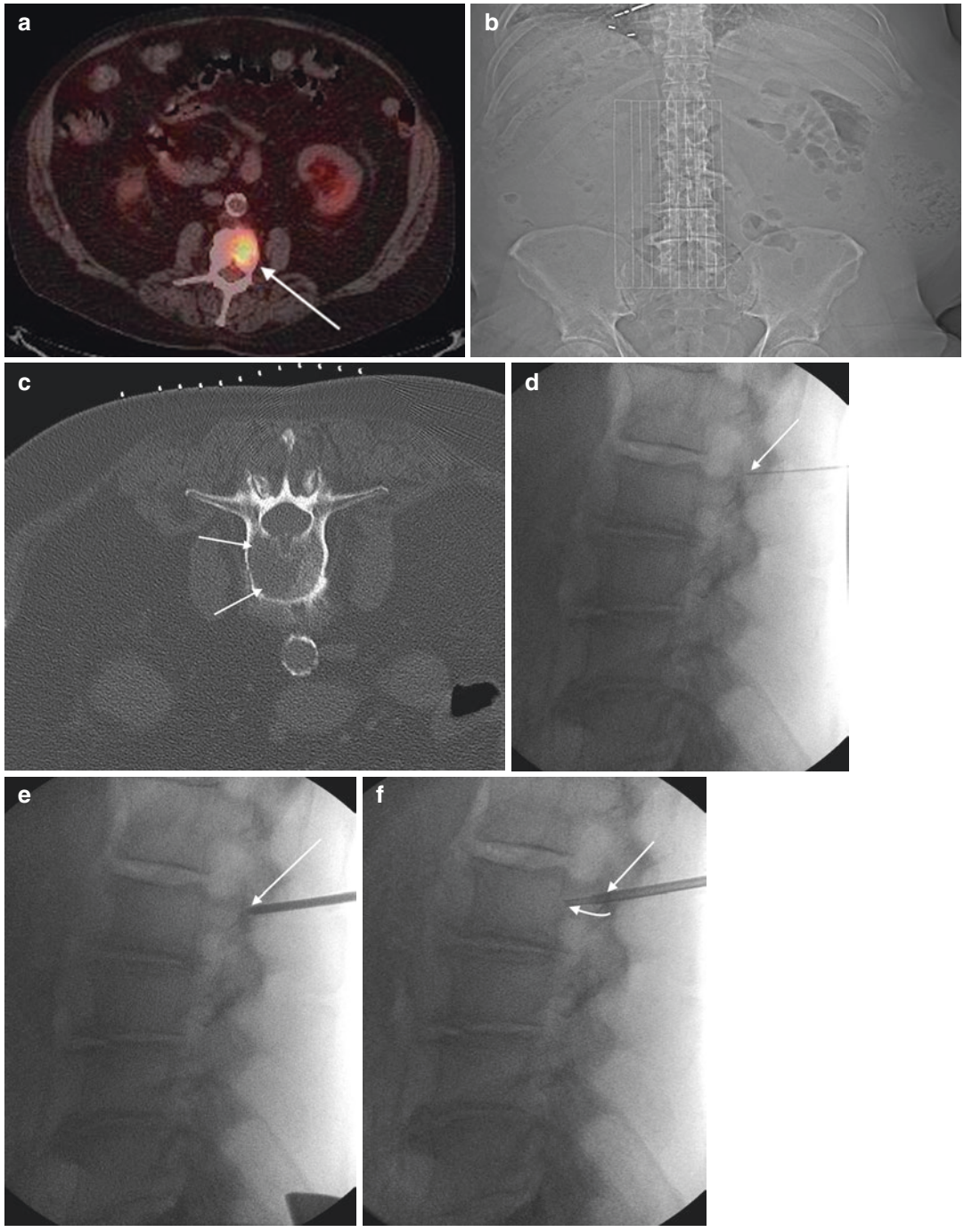
6.8.1.2 Staff Factors

As with any image-guided biopsy, it is necessary to inform the staff (such as technicians, nurses, and anesthesiologists) of the type of spine biopsy that will be performed. The biopsy team should perform patient and procedure verification. Discussion of patient positioning for optimal imaging and biopsy site access is important so as to reduce the need to reposition the patient during the procedure. Specifically, it is important to note on which side of the patient the operator will be working and whether to place the patient in the gantry head or feet first. This will allow nursing and ancillary staff to position the procedure table and monitoring equipment in the most optimal locations and allow the technologist to select the appropriate imaging position on the scanner. Nursing should be informed of the level of the anesthesia plan so as to allow appropriate monitoring and support as well as access to medications.

6.8.1.3 Anesthesia

Both local and intravenous anesthesias are commonly employed for lumbar spine biopsy. Local anesthesia with 1% or 2% lidocaine is administered at the skin surface and within the deep soft tissues. It is important to aspirate prior to injection of anesthetic to ensure that a blood vessel is not inadvertently injected. When necessary and clinically appropriate, intravenous medications such as midazolam and fentanyl can be administered to decrease procedure-related anxiety and reduce patient pain, respectively. Occasionally, it may be necessary to perform a lumbar spine biopsy with an anesthesiologist present when intravenous or general anesthesia is required for the case. Situations that require general anesthesia are intractable pain in adult patients and spine biopsy procedures in the pediatric population.

Fig. 6.13 An 80-year-old male with a lung mass. Axial fused PET-CT image (**a**) shows focal FDG uptake (*arrow*) within the left side of the L2 vertebral body. Scout frontal CT image (**b**) with skin grid in place shows a large body habitus. Axial CT image (**c**) with skin grid in place shows large lytic lesion within the left side of the vertebral body (*arrows*). Due to the patient's large size, the biopsy system could not be safely placed within the CT scanner gantry, and the patient was transferred to the fluoroscopy suite. Lateral fluoroscopic image (**d**) shows the use of a spinal needle to anesthetize the periosteal surface of the left pedicle. Lateral fluoroscopic image (**e**) shows the bone needle entering the posterior pedicle (*arrow*). Lateral fluoroscopic image (**f**) shows coaxial insertion of a trephine bone biopsy needle (*curved arrow*) via a guide cannula (*arrow*) into the anterior aspect of the left pedicle. Simultaneously acquired frontal fluoroscopic image (**g**) shows the guide cannula (*arrow*) and the position of the biopsy needle tip relative to the medial pedicle margin. Now that an adequate transpedicular position of the needle has been confirmed, the bone biopsy needle can be safely advanced into the vertebral body (*arrows*) as shown on the lateral (**h**) and frontal (**i**) fluoroscopic images. This biopsy confirmed the presence of metastatic lung cancer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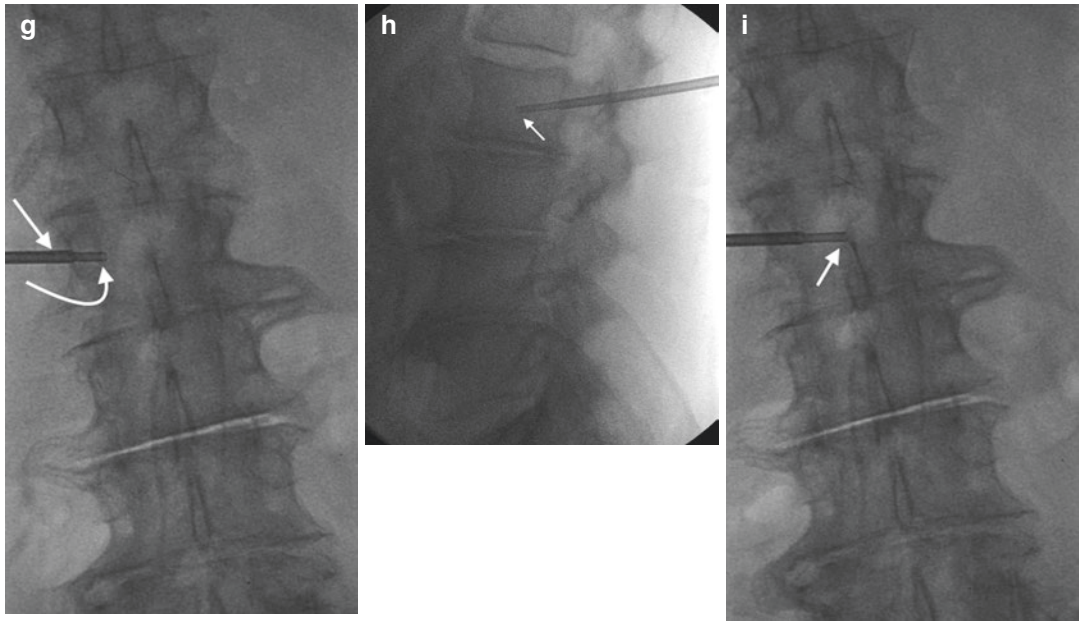


Fig. 6.13 (continued)

Regardless of the type of systemic anesthesia, appropriate monitoring of blood pressure, oxygen saturation, heart rate, and cardiac activity with electrocardiography is essential.

6.8.1.4 Patient Preparation

Before the procedure, certain medications may need to be stopped, such as anticoagulants, which should be ideally suspended several days prior or bridged based on provider and pharmaceutical recommendations (refer to the Chap. 2). Antibiotic therapy might be required for prophylaxis in immunocompromised patients (Santiago et al. 2014). When the biopsy procedure is concerned with identifying infectious pathogens, antibiotic therapy should be initiated after the biopsy procedure is performed in order to maximize the chances of isolating the microorganism

The patient is most commonly placed on the procedure table in the prone position. An oblique or decubitus position may be necessary if the patient cannot tolerate the prone position, such as in patients with excruciating pain in the prone position, recent abdominal surgery, or an abdominal ostomy site. Once positioned, a skin grid can be placed over the lumbar region at the desired level prior to CT imaging in order to select and mark the skin entry site. If performing the procedure with fluoroscopy, a radiopaque instrument, such as a towel clamp or hemostat, can be used to identify the desired biopsy location with imaging and marking the skin before or after sterile prepping. Once an entry site has been marked for biopsy, the back is prepped with using strict aseptic technique. A sterile drape is then placed around the skin entry site in order to provide a larger sterile field (Fig. 6.14).

> Careful pre-procedural attention to patient positioning and needle trajectory will decrease the need for patient and needle repositioning at the time of biopsy.

6.8.2 Technique

6.8.2.1 CT Guidance

Initial assessment of the needle path trajectory is typically performed with a radiopaque skin grid placed over the lumbar region at the desired level for biopsy. Scout CT images in both the frontal

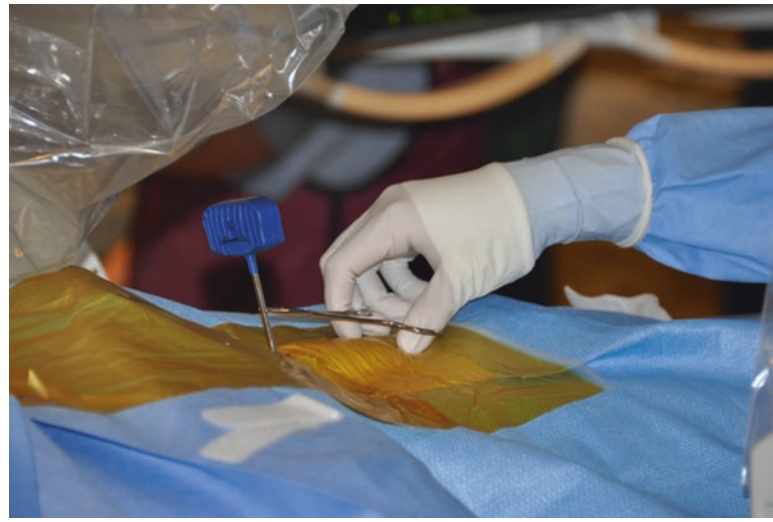


Fig. 6.14 Photograph obtained during a fluoroscopic biopsy procedure shows the sterile field

and lateral projections should be obtained. Always count the vertebra on the scout images to confirm the region of interest; this will help to prevent a wrong level biopsy. The operator should instruct the CT technologist to focus the field of view (FOV) over the region of interest and ensure that the skin surface is included in order to visualize the grid. If the desired trajectory is at a cranial or caudal angle to routine axial imaging, the FOV can be angled to allow for gantry angulation, if available, simulating the needle path on the lateral scout (Fig. 6.15). This typically requires axial scanning mode rather than helical or spiral scanning. Slice thickness less than or equal to 3 mm is important to ensure proper visualization of bony anatomy with respect to the lesion. CT scanning of the region of interest is then performed. Images can be reconstructed with soft tissue and/or bone algorithm to allow visualization of the biopsy site (Fig. 6.16). In general, soft tissue windows are necessary for soft tissue lesions and bone windows for lesions within the vertebral bodies or posterior elements (Fig. 6.17). Once the intended biopsy site is identified, the operator can choose the slice positioning and draw a line from the radiopaque marking on the image to the lesion, establishing the needle trajectory and depth. Depth measurement of the lesion from the skin site allows for proper selection of the biopsy needle length. The number of the radiopaque mark can then be ascertained by counting from either end of the visualized markings. Once the position is determined, the table can be moved into the desired slice position, and a red line can be illuminated over the skin surface with the CT laser alignment system, corresponding to the axial CT image at the skin entry site. This allows appropriate marking of the grid at the corresponding slice position. The grids used for CT-guided biopsies are porous, and, therefore, a skin marker will transfer an ink mark from the grid to the patient's skin. The grid can then be removed, and the table moved out of the gantry to allow access for sterile preparation of the patient's back.

> Always count the vertebra on the scout images to confirm the vertebral level of interest; this will help to prevent a wrong level biopsy.

Once the back has been prepped with Betadine scrub and/or chlorhexidine scrub and appropriately draped, the skin at the marking site is anesthetized with a local anesthetic agent, such as 1 or 2% lidocaine. Deep soft tissue anesthetic is administered at this time. A 22 or 20 gauge spinal needle is advanced through soft tissues to the level of the periosteum or deep soft tissue adjacent to the biopsy site. It is important to periodically

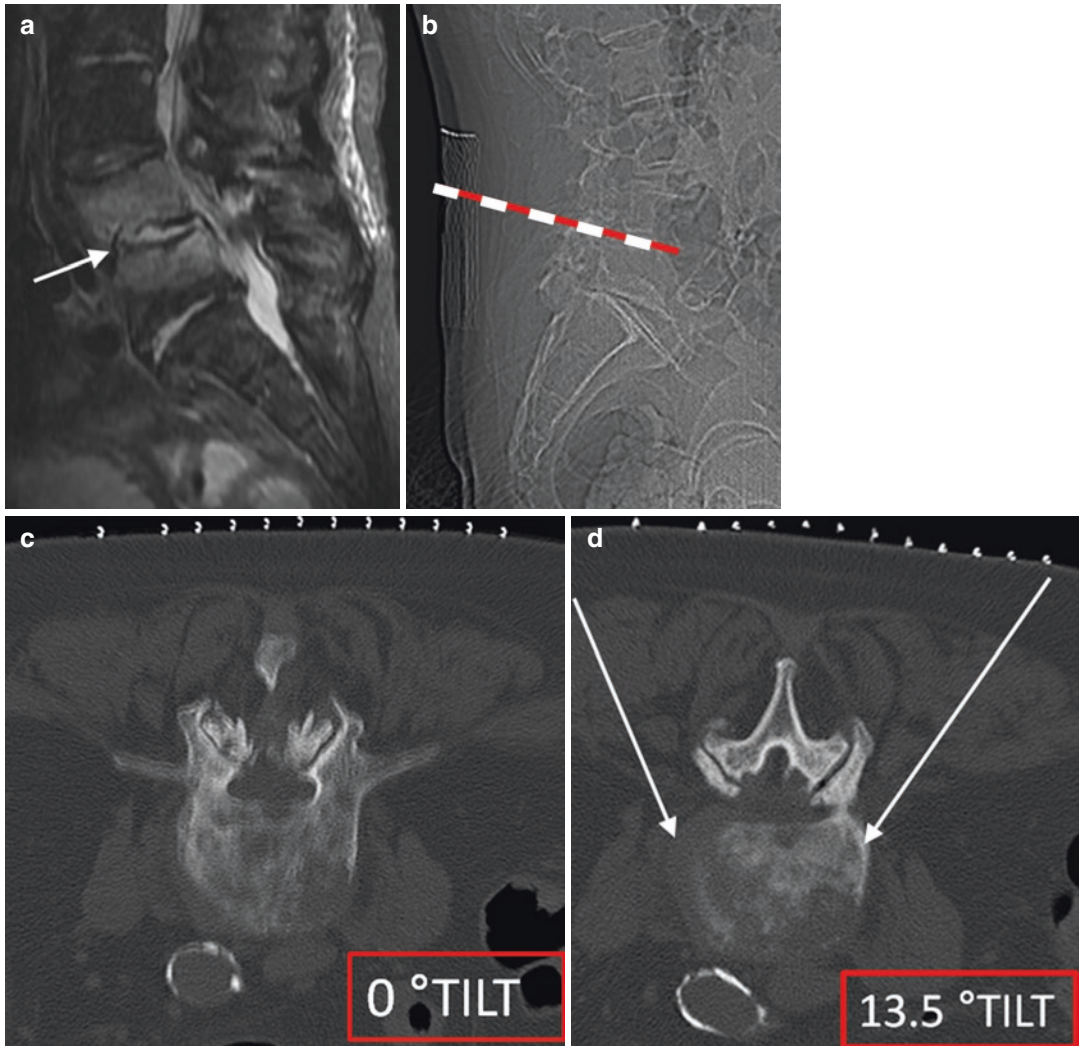


Fig. 6.15 Use of CT gantry angulation. T2-weighted sagittal image (**a**) shows findings compatible with L4–L5 disk infection (*arrow*). Scout lateral CT image (**b**) shows the angulation (*dashed line*) that the gantry is adjusted to in order to access the disk. Axial CT image (**c**) with no gantry angulation; the disk is not accessible. Axial CT image (**d**) with 13.5° of gantry angulation provides a trajectory to the disk (*arrows*)

image during needle advancement to ensure a safe advancement as well as proper position and depth of the spinal needle. Once in the desired location, an anesthetic agent can be administered to anesthetize the periosteum, allowing significant reduction in pain related to bony entry with a bone biopsy needle (Fig. 6.12). Once deep anesthesia has been administered, the needle can be left in place to serve as a guide for the bone biopsy needle or can itself be used for coaxial technique if a guide needle was used (Fig. 6.18).

CT-guided percutaneous lumbar spine biopsy can be performed with tandem needle technique or with direct coaxial technique.

If the operator chooses to use a trephine needle for biopsy, a dermatotomy made with a number 11 scalpel is required at the skin entry site. Manual blunt dissection at the dermatotomy allows easier passage of the needle through the

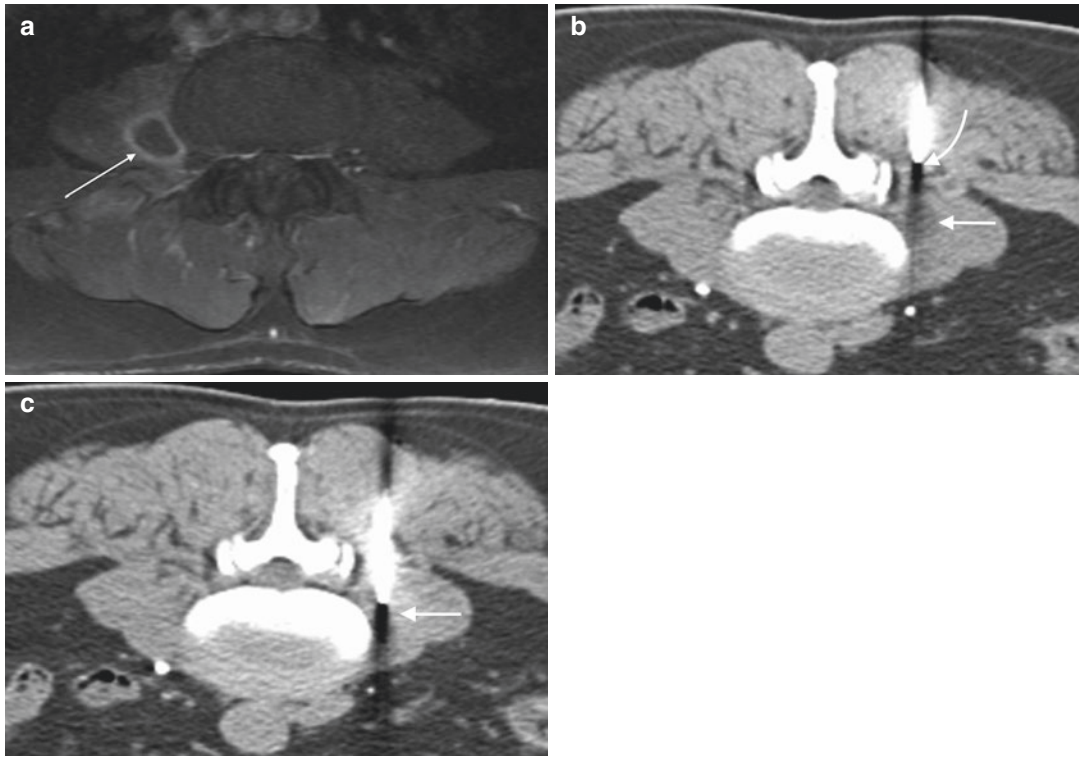


Fig. 6.16 A 43-year-old male with low back pain, fever, and elevated ESR. Fat-suppressed contrast-enhanced T1-weighted axial image (**a**) shows a ring-enhancing lesion (*arrow*) within the right psoas muscle. In the clinical context, this was thought to be a psoas abscess. Axial CT image (**b**) obtained with soft tissue algorithm in order to better visualize the right psoas abscess (*arrow*) so that the biopsy needle (*curved arrow*) could be readily advanced to the target. Axial CT image (**c**) in soft tissue algorithm shows the needle within the abscess collection (*arrow*); purulent material was aspirated from the abscess

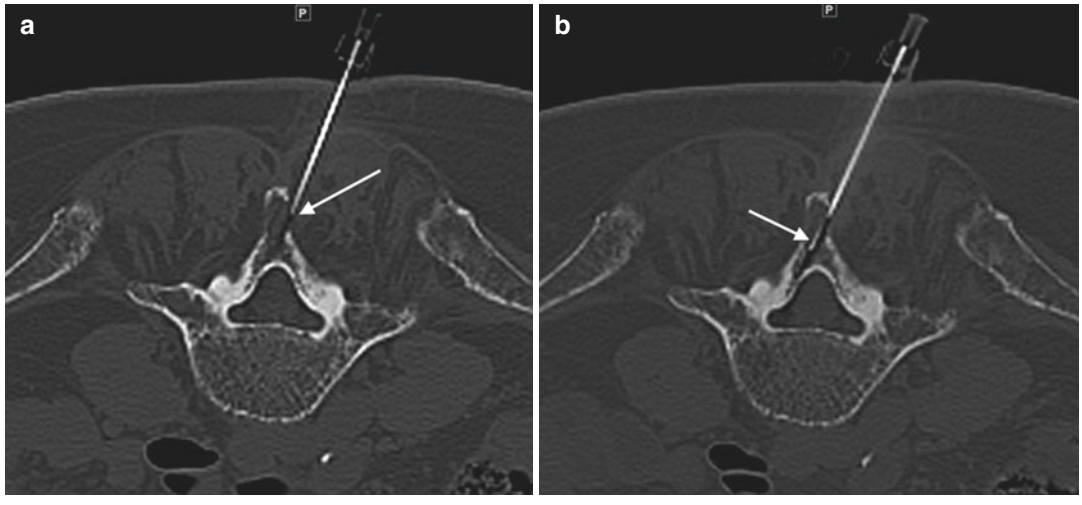
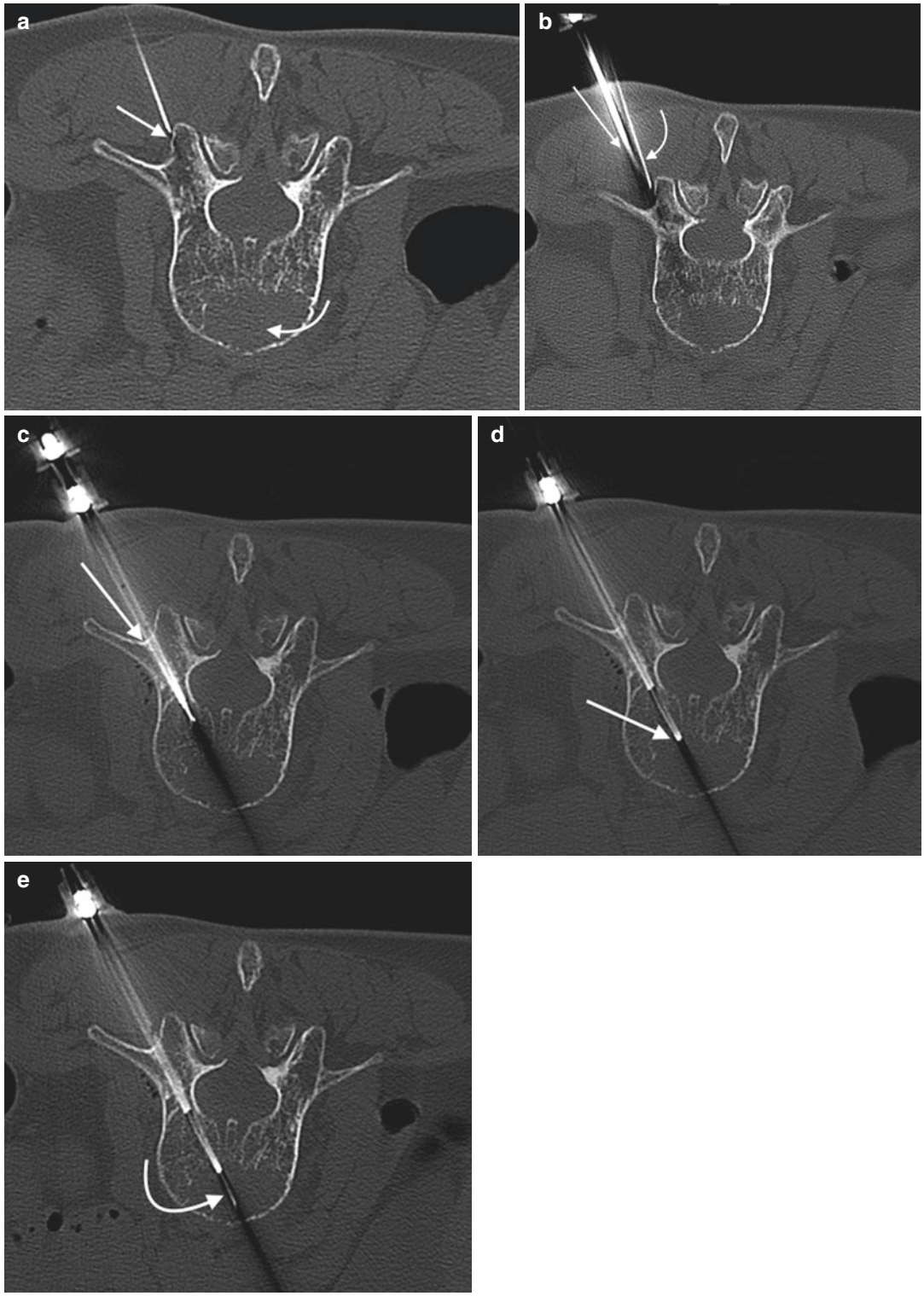


Fig. 6.17 Use of bone window algorithm for a posterior element (spinous process) lesion. Axial CT image (**a**) shows 18 gauge spinal needle (*arrow*) at the margin of a lytic spinous process lesion. Axial CT image (**b**) shows coaxial insertion of 25 gauge spinal needle for fine-needle aspiration of the lesion (*arrow*). The cytology was positive for myeloma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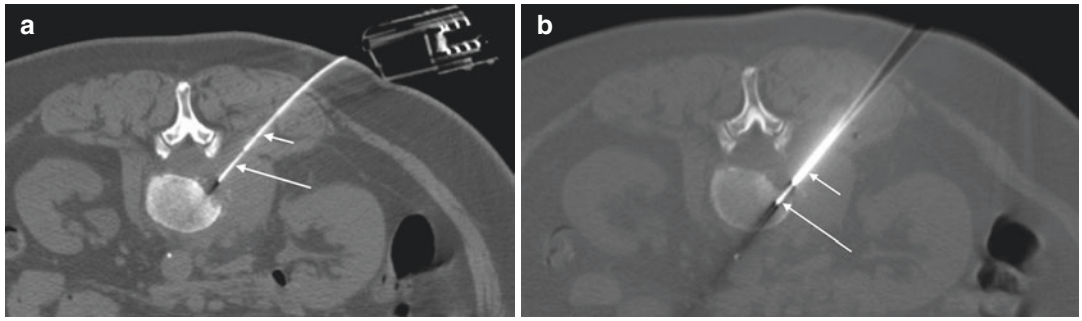


Fig. 6.19 A 64-year-old female with focal upper low back pain. Axial CT image (**a**) shows use of coaxial guide cannula (*small arrow*) and cutting needle (*large arrow*) in order to biopsy a large paraspinal soft tissue component of this lumbar mass. Once sufficient soft tissue cores were obtained, the guide cannula was advanced closer to the vertebral body (*small arrow*) as shown on the axial CT image (**b**). A bone biopsy needle (*large arrow*) was then used to obtain bone cores from this lesion. The bone cores show histopathologic evidence of acute inflammation consistent with acute osteomyelitis. The soft tissue cores, which were sent to both pathology and microbiology, were positive for bacterial growth on the microbiologic analysis. This case reinforces the useful practice of submitting specimens for both pathologic and microbiologic analysis, whenever the diagnosis is in question

soft tissues. Alternatively, a dermatotomy may not be necessary if an 18 or larger gauge needle is used, as these needles can easily pass through the skin. Once the needle enters the patient's body, it is advanced in the trajectory established on initial planning of site selection and needle path. For access to the lumbar vertebral body or disk space, this is often at a 20–40 ° oblique trajectory from midline and may include cranial or caudal angulation of the needle. When advancing the needle, it is again important to utilize periodic CT imaging to ensure safe and appropriate placement in regard to both obliquity and depth.

Once the needle reaches the bone, disk, or soft tissue that is to be biopsied, further advancement for sampling of the lesion depends on needle type, such as trephine, cutting, and fine needle (Fig. 6.19). For access into the vertebral body, a trephine needle is preferred. This type of needle allows for penetration of cortical bone and easy advancement through the vertebral body. Progression through the cortex can be achieved by manually twisting the needle or with the use of a mallet or hammer. Some trephine biopsy systems provide a drill, which can be coaxially inserted into the introducer needle and used to drill through the cortex and bone. The drill creates a path anterior to the introducer needle to allow for needle advancement manually along this path. Coaxial cutting needles can be used for sampling of disk space and soft tissue lesions, which tend to be smaller gauge needles that allow for core sampling (Yaffe et al. 2003). Biopsy of some lesions may not be feasible with trephine or cutting needle systems and may instead require fine-needle aspiration (FNA). The operator may prefer FNA for small soft tissue lesions or highly vascular lesions for accuracy and safety, respectively (Fig. 6.20).

Once the needle position is confirmed by CT imaging to be at the margin or within the lesion, measurements can be taken on imaging from the anterior margin of the needle to the anterior mar-

Fig. 6.18 Tandem needle technique. Axial CT image (**a**) shows use of a 20 gauge spinal needle (*arrow*) to anesthetize the posterior pedicle surface in order to facilitate transpedicular access to an anterior lytic L3 vertebral body lesion (*curved arrow*). Axial CT image (**b**) shows insertion of a bone biopsy needle (*arrow*) alongside the spinal needle (*curved arrow*). Axial CT image (**c**) shows removal of the spinal needle and advancement of the biopsy needle via a transpedicular approach (*arrow*). Axial CT image (**d**) shows coaxial advancement of a core biopsy needle to the proximal margin of the lytic lesion (*arrow*). Axial CT image (**e**) shows coaxial placement of a 25 gauge spinal needle (*curved arrow*) into the lesion; FNA was performed because there was a clinical concern for a hypervascular lesion. Pathology yielded a diagnosis of multiple myeloma

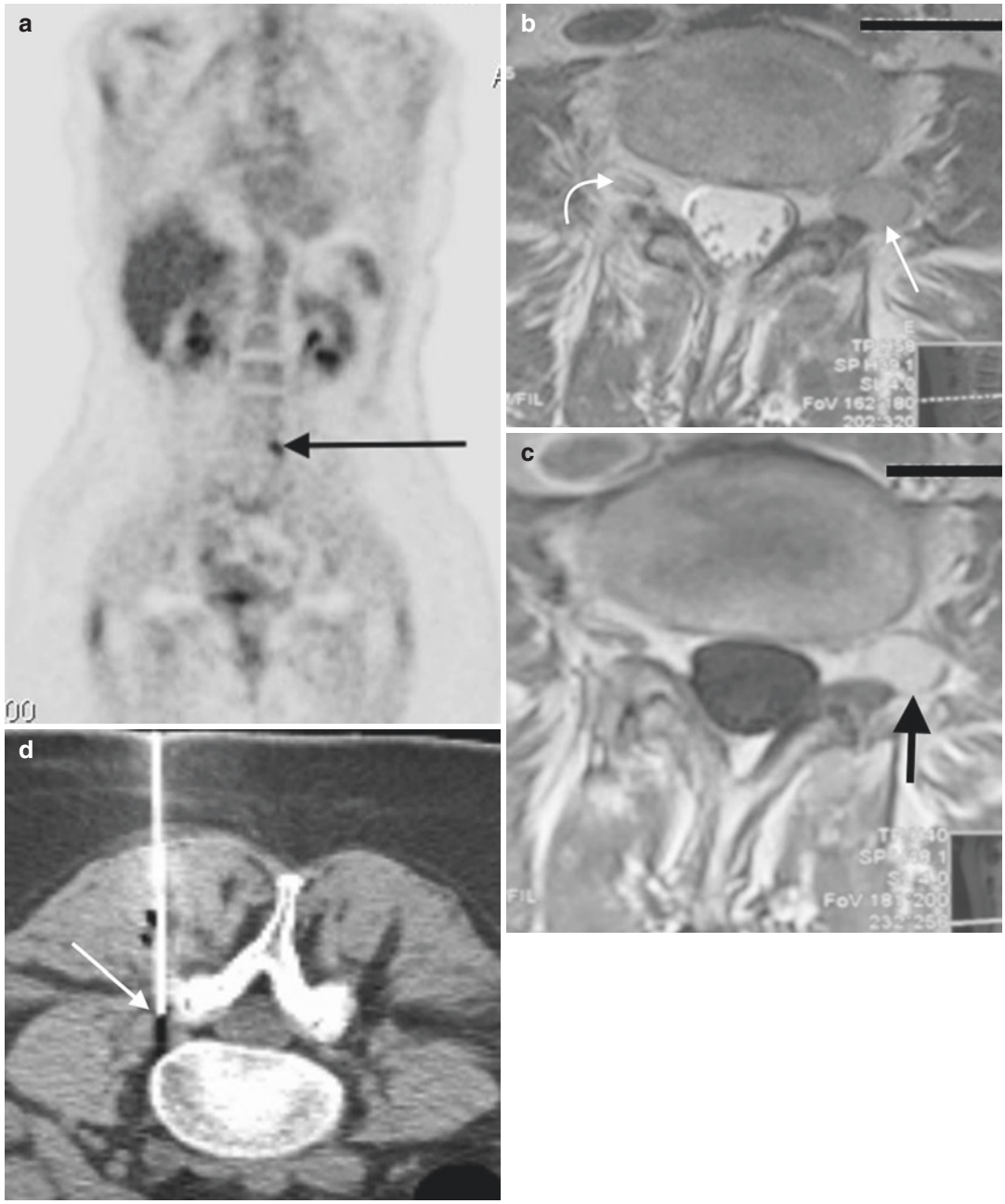


Fig. 6.20 A 51-year-old female with breast cancer and left L4 radiculopathy. Posterior projection from PET examination (**a**) shows focal FDG uptake in the lower left lumbar spine (*arrow*). T2-weighted axial image (**b**) shows focal enlargement and hyperintensity within the left L4 dorsal root ganglion (*arrow*); compare to the normal right dorsal root ganglion (*curved arrow*). Close-up view of contrast-enhanced T1-weighted axial image (**b**) shows intense enhancement (*arrow*) within the dorsal root ganglion. Axial CT image (**c**) in soft tissue algorithm shows the placement of a guide needle (*arrow*) at the proximal margin of the enlarged dorsal root ganglion for the purpose of performing FNA. Two passes with a 25 gauge needle confirmed the presence of metastatic breast carcinoma

gin of the lesion, vertebral body, or disk space. This allows the operator to determine the approximate depth that the biopsy needle can be advanced through the introducer needle in order to ensure both accurate sampling and to avoid incorrect needle placement through the anterior margin of the spine or soft tissue lesion. The biopsy needle is then advanced into the lesion. Many biopsy systems, including both trephine and cutting needles, provide markings or measurements on the needle to allow the operator to determine the position of the biopsy needle tip in relation to the anterior margin of the introducer needle.

When the biopsy needle is advanced to the desired depth, a CT image is obtained to confirm needle placement (Fig. 6.12). In a trephine biopsy system, the biopsy needle is then removed, usually with slight aspiration to ensure that the sample remains in the needle chamber upon extraction. The sample can then be pushed out of the biopsy needle with a needle pusher, which is provided with most biopsy systems. In cutting needle systems, the needle can be directly removed after a core sample has been taken. The core is then transferred to the appropriate solution, such as formalin, for future analysis. With coaxial biopsy systems, the introducer or guide needle can remain in place at the lesion margin such that additional biopsy needles can be sequentially and safely inserted as needed in order to obtain additional biopsy specimens. In the setting of FNA, the samples can be provided to an on-site cytopathologist or cytopathology technician for assessment of adequate cellularity. Sampling of vertebral body, disk space, or soft tissue lesions should be performed several (approximately three times) to ensure appropriate volume of tissue for analysis. In the setting of core biopsy of the vertebral body, this may not always be possible. If the core is visualized to be large enough, only one sample may be required. Alternatively, when FNA is performed, it is often necessary to make three to five passes with 22–25 gauge needles for adequate diagnostic cellularity. Once the pathologist or cytotechnologist is satisfied that they have adequate specimen for diagnosis, the FNA procedure can be stopped. When sampling the paraspinal soft tissues for suspected infection, needle aspiration is performed first, especially if there is a fluid collection. If necessary, a drainage catheter can be placed (Fig. 6.21). In those cases where no material can be aspirated, a small amount of normal sterile saline or local anesthetic can be infiltrated into the area and re-aspirated. A core needle biopsy can also be utilized to obtain tissue, and this too can be sent for microbiologic analysis (Fig. 6.22).

6.8.2.2 Fluoroscopic Guidance

Fluoroscopic guidance can often be used to biopsy vertebral body and disk space pathology. In the setting of diffuse pathologic involvement of the vertebral body, fluoroscopy is a preferred modality due to the real-time assessment of needle advancement and reduced procedure time (Fig. 6.23). Additionally, fluoroscopy provides excellent visualization of and prompt access to the disk space. One advantage fluoroscopic guidance has over CT is the ability for significant craniocaudal angulation as well as right and left obliquity, allowing for positioning of the image intensifier over the desired bone or disk space in order to facilitate a needle trajectory that may not be possible with CT imaging and with decreased need for patient repositioning. This is most helpful when a biopsy of the L5–S1 disk space is required. A major disadvantage of fluoroscopy is the inability to visualize and evaluate soft tissues, and therefore, CT must be utilized when the target lesion is located within the paraspinal soft tissues. When smaller, focal lesions are present or there is need for confirmation of biopsy needle placement within the lesion, CT guidance is preferred.

Slight differences in patient preparation are required when performing lumbar spine biopsy with fluoroscopy when compared to CT. Prior to sterile prep, the entry site can be established by rotating the image intensifier to the desired location in the frontal projection. The tip of a hemostat is pressed over the skin with simultaneous

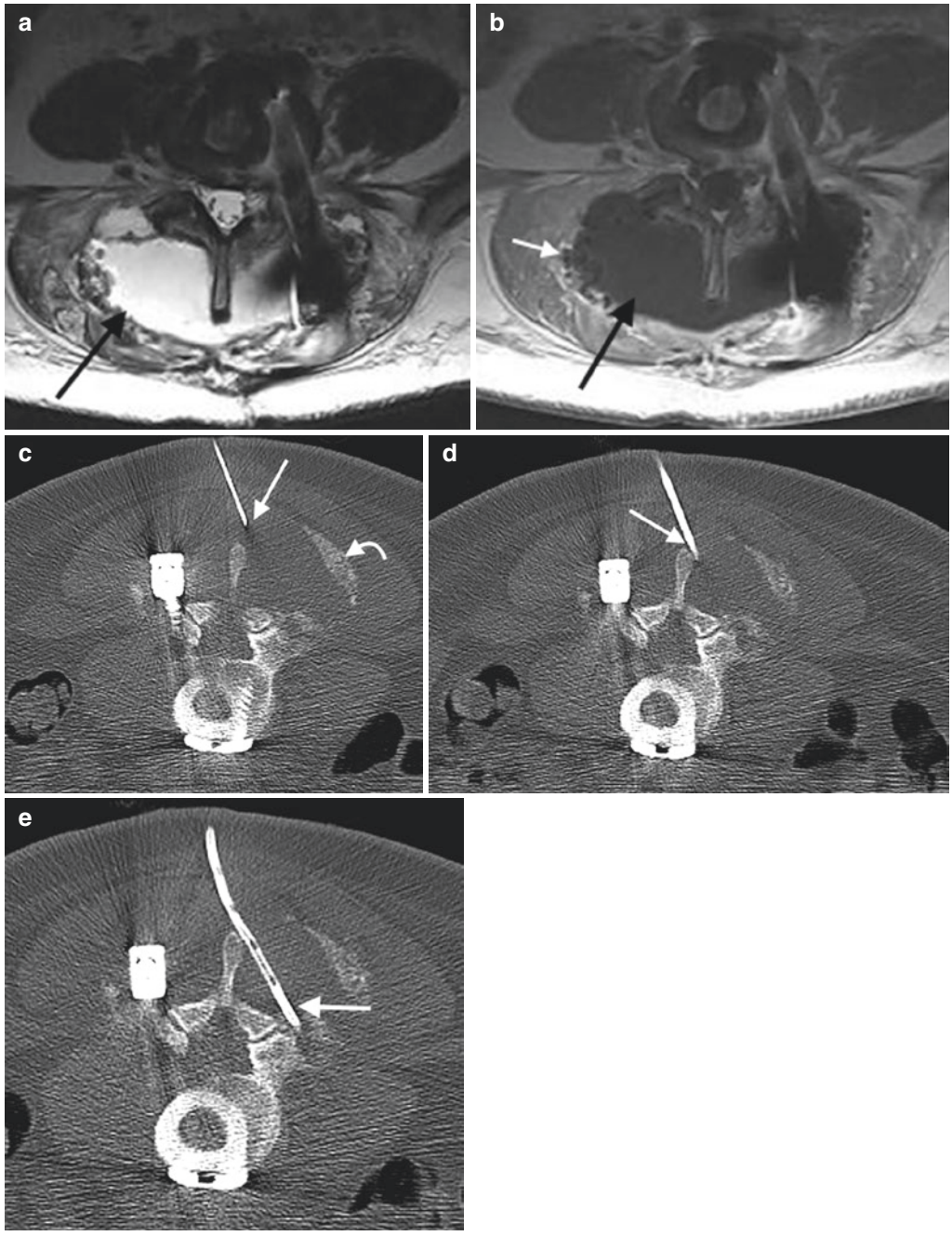


Fig. 6.21 A 37-year-old female with back discomfort following an anterior and posterior lumbar spinal fusion procedure. T2-weighted axial image (**a**) shows a large hyperintense posterior paraspinal fluid collection (*arrow*). Contrast-enhanced T1-weighted axial image (**b**) shows a hypointense fluid collection (*large arrow*) with no abnormal enhancement; note the multiple small punctate hypointense foci (*small arrow*) at the periphery of the collection. Axial CT image (**c**) shows an introducer needle at the periphery of the collection (*arrow*) from which a few milliliters of clear straw-colored fluid were initially aspirated; peripheral heterotopic bone formation (*curved arrow*) accounts for the low-signal foci on the MRI. Bone morphogenic protein was used in the posterior fusion surgery. Axial CT image (**d**) shows advancement of a trocar-bearing multi-sidehole catheter (*arrow*) into the collection. Axial CT image (**e**) shows drainage catheter in place (*arrow*). The microbiologic analysis was negative

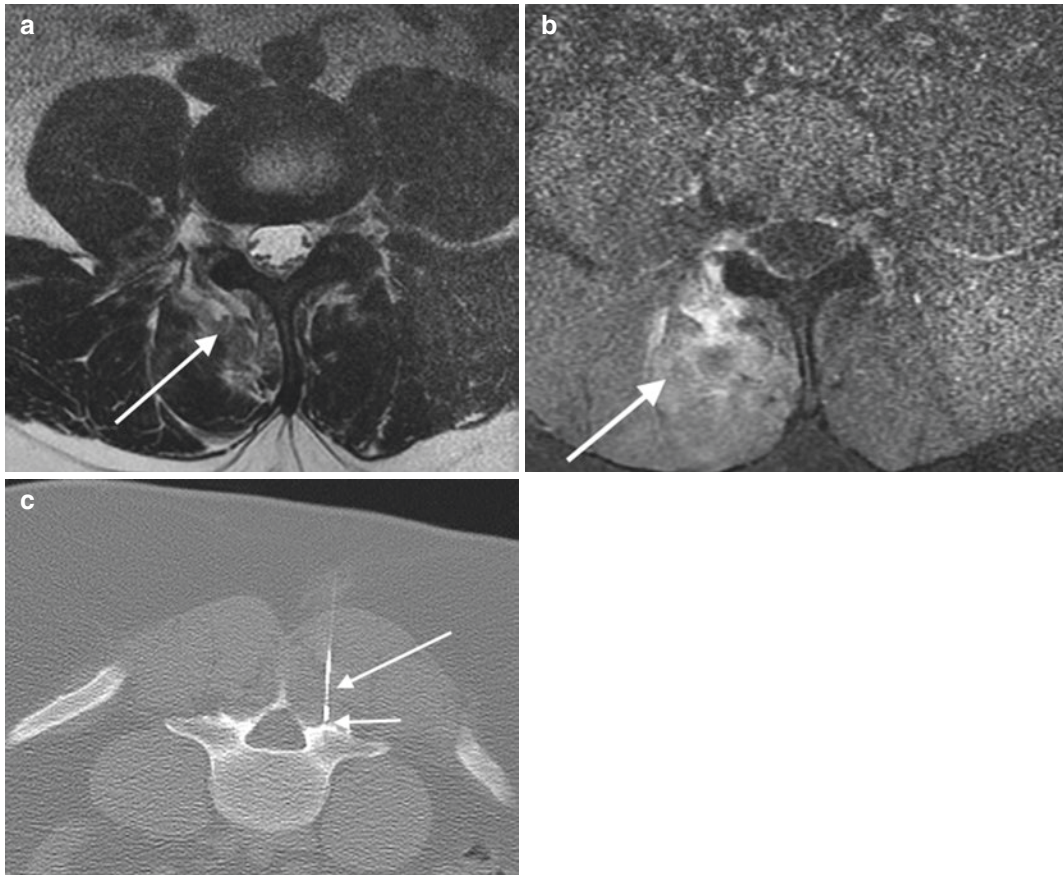


Fig. 6.22 A 31-year-old male with low back pain and elevated ESR (68) and CRP (300). T2-weighted axial image (**a**) shows increased signal intensity within the right posterior paraspinal musculature (*arrow*). Fat-suppressed contrast-enhanced T1-weighted axial image (**b**) shows patchy focal enhancement in this location (*arrow*). Axial CT image (**c**) shows a small cutting needle placed at the level of the soft tissue abnormality (*large arrow*) and advanced to the margin of the facet joint (*small arrow*). This small core of soft tissue was positive for coagulase-negative *Staphylococcus*, and the patient was immediately started on the appropriate antibiotic therapy

imaging to determine the point of needle entry at the skin. A mark is then made at this site and allows the operator to prep a field around this location. Once the back has been prepped with sterile technique, anesthesia and dermatotomy can be performed in a similar fashion as with the CT technique. The needle is then advanced under fluoroscopic guidance. It is important to keep the needle and osseous landmarks within the center of the field of view of the fluoroscope as the needle is advanced. This reduces parallax error and improves targeting of the needle. A hemostat can be used to hold the needle in place while imaging with fluoroscopy so as to avoid radiation exposure to the operator's hand. The needle should parallel the plane of frontal imaging and be seen as a "dot." This allows directed advancement of needle along the established trajectory. When the needle has advanced to a depth several centimeters away from the pedicle or disk space, the tube can be rotated to the lateral position to assess needle depth. Once the needle has been advanced to the disk space or pedicle, it can be further advanced into the desired location with continuous lateral imaging. It may be necessary to rotate the tube from the frontal and lateral projections several times through needle advancement to confirm both needle placement within the vertebral body or disk space as well as the depth of the needle and the location of the needle tip relative

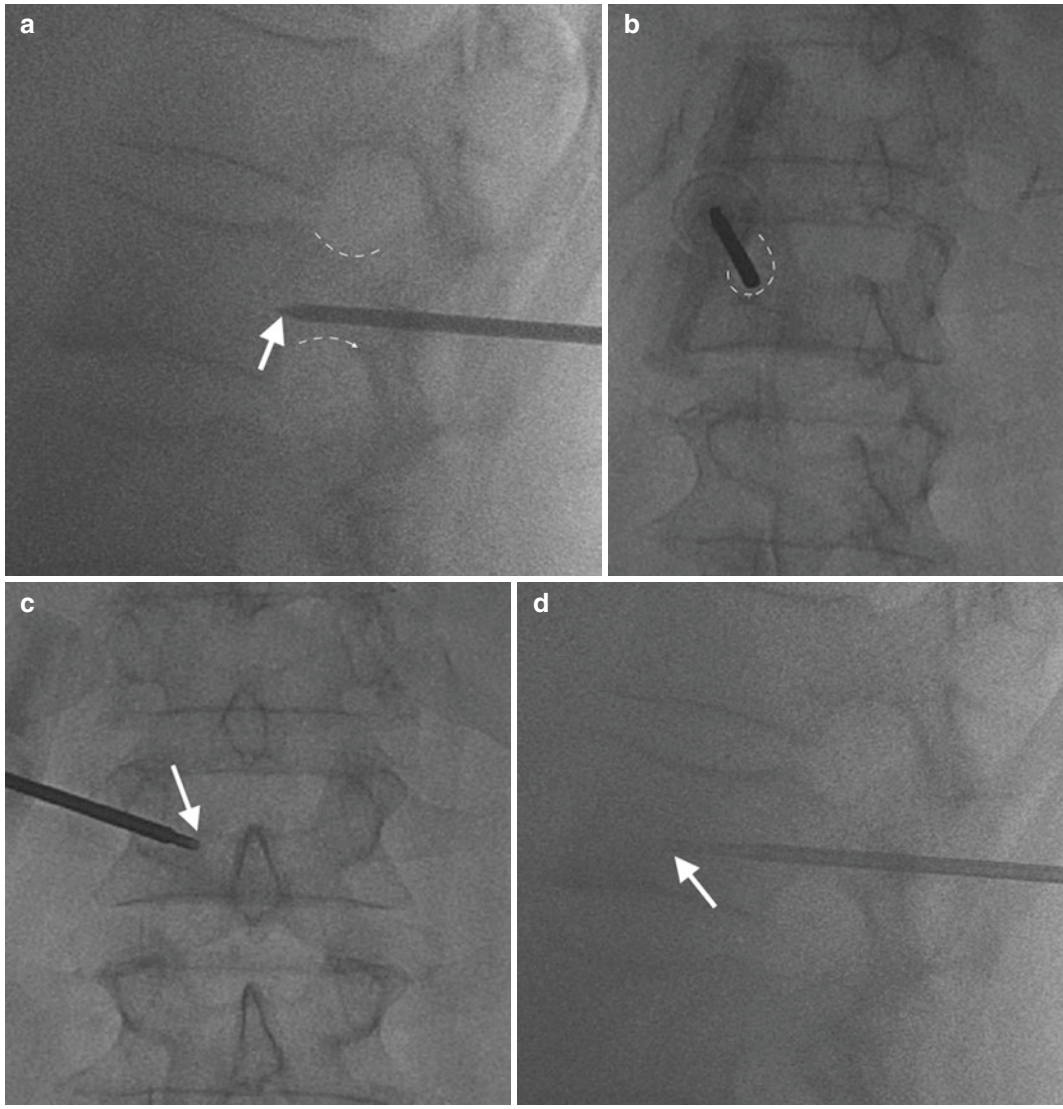


Fig. 6.23 A 76-year-old male with history of lung cancer and a diffusely abnormal L1 vertebra on a PET-CT study. Lateral fluoroscopic image (**a**) shows transpedicular needle placement (*arrow*), not the superior and inferior margins (*dashed lines*) of the pedicle. Oblique fluoroscopic image (**b**) shows the position of the needle within the pedicle (dashed semicircle). Frontal fluoroscopic image (**c**) shows coaxial advancement of a bone needle (*arrow*) into the vertebral body. Lateral fluoroscopic image (**d**) shows the position of the needle (*arrow*) within the vertebral body. Four bone cores were obtained, and the biopsy was positive for metastatic adenocarcinoma

to critical structures (Fig. 6.23). A biplane fluoroscopy unit, if available, can eliminate the necessity for these multiple movements of the multidirectional fluoroscope.

6.8.2.3 Fluoroscopic Vertebral Body Biopsy

Percutaneous access into a lumbar vertebral body is often performed through a transpedicular approach (Fig. 6.23). Pre-biopsy imaging review is essential to determine if the lesion can be accessed with fluoroscopic guidance. Diffuse involvement of the vertebral body allows for sampling within any portion of the vertebrae without great concern for missing the lesion. Similarly, fluoroscopic guidance may be used to access a large vertebral body lesion or a sclerotic lesion. A transpedicular approach is performed by rotating

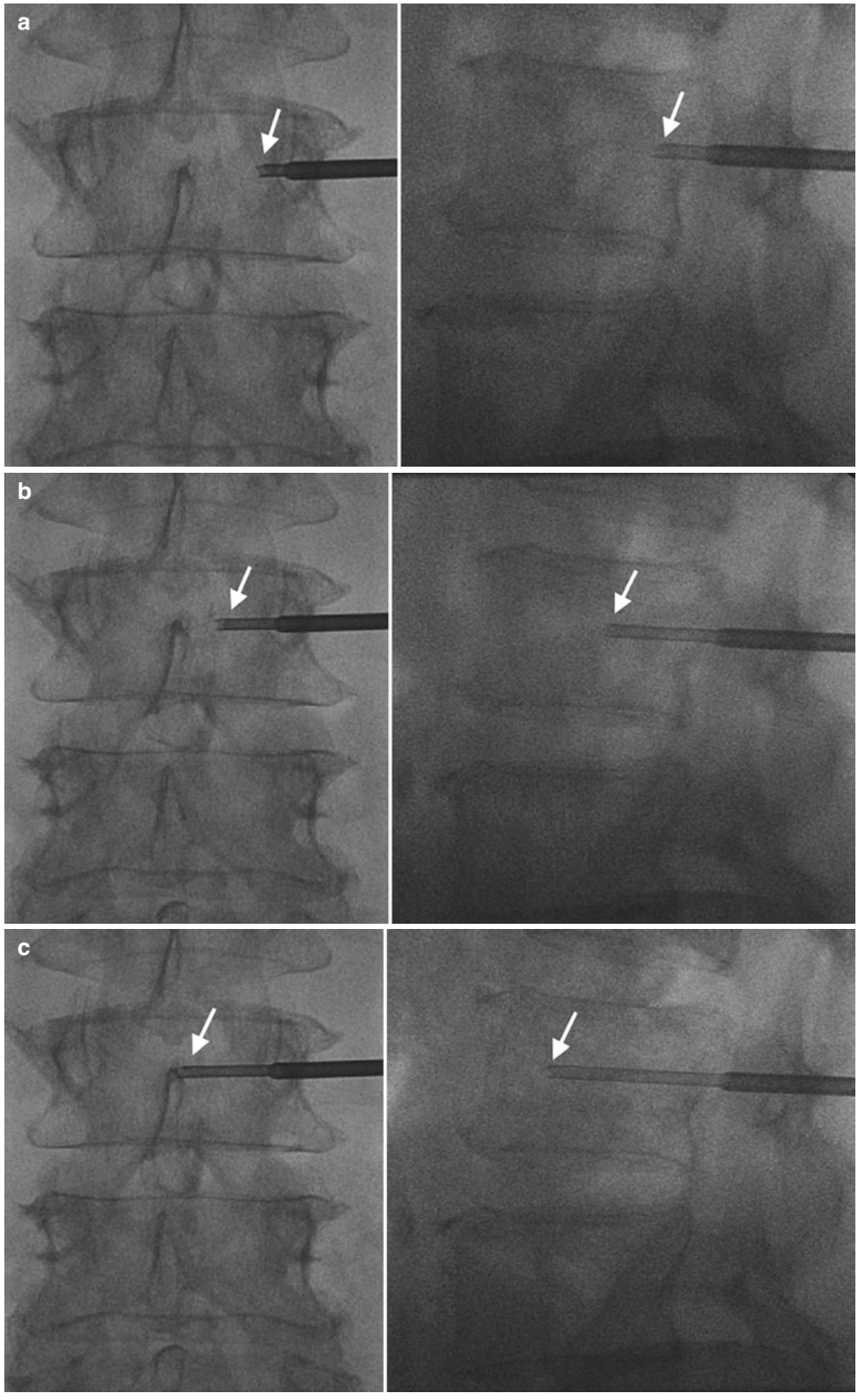
the fluoroscopic tube approximately 30° from midline. This allows visualization of the "Scotty dog" within the lumbar spine. The eye of the Scotty dog represents the pedicle, which can be overlapped with a portion of the vertebral body (Fig. 6.23). This creates a needle trajectory that passes from the skin though the pedicle into the vertebral body. Lateral and frontal imaging during needle advancement will confirm the correct needle path into the pedicle as well as needle depth once with the vertebral body (Fig. 6.24). A coaxial approach with a biopsy needle system, similar to what is used with CT guidance, can also be utilized with fluoroscopic guidance. In certain situations, for example, a more posterior and paramedian location of a lesion, it may be necessary to access the lumbar vertebral body with an extrapedicular approach such as a parapedicular approach. This facilitates steeper angulation of the biopsy needle into the vertebral body and allows for access to the posterior and median portion of the vertebral body.

6.8.2.4 Fluoroscopic Disk Space Biopsy

In the setting of suspected diskitis and/or osteomyelitis, biopsy may be requested to confirm the diagnosis of spine infection and to provide information on the type of organism involved in order to optimize antibiotic therapy (refer to the Chap. 9). Although CT can be used to biopsy the disk space and paraspinal fluid collections, fluoroscopy offers several advantages over CT. Oblique and craniocaudal angulation on fluoroscopy allows the operator to directly visualize the disk space and vertebral endplates. The fluoroscopy tube is rotated so that the disk space and endplates are parallel and the position of the superior articular process of the vertebral body below the disk space overlaps the midportion of the disk space in this projection. The needle is advanced in a path that lies lateral to the superior articular process (Fig. 6.7). The extent of medial-lateral or oblique angulation will place the superior articular process anywhere from one-third to half-way across the full extent of the disk as visualized on the oblique-frontal view. Steeper angulations of the fluoroscope allow for needle placement along the median aspect of the disk space, whereas a less steep approach allows for access to the lateral aspect of the disk space. This technique allows for safe passage of the needle into the disk space and avoids the exiting lumbar nerve root. It may be necessary to sample both vertebral body/endplate and intervertebral disk in order to establish a diagnosis of infection. Core material in this setting can and, whenever possible, should be sent for both microbiology and surgical pathology analysis. Tissue assessment for both microorganism and histologic evidence of infection has been shown to provide a greater diagnostic yield than either alone (Michel et al. 2006). Fluoroscopic guidance allows for transpedicular access into the disk-endplate complex. The tube is rotated to allow for overlap of the pedicle of either vertebral body bordering the disk space with the adjacent vertebral body. This provides an angulated needle trajectory which will allow passage of the needle through both endplates and the intervertebral disk.

Core samples can be divided, as necessary, and should be placed in sterile containers for microbiologic analysis. It is important to avoid placement of microbiology samples in formalin to avoid reducing the ability to analyze the tissue for microorganisms. Any aspirated fluid or pus should be sent for microbiologic assessment only. For histology, core samples are placed in a formalin container. Special stains for microorganisms can also be performed with histological assessment of the tissue.

Fluoroscopy can be used to guide percutaneous biopsy of the lumbar spine in the setting of diffuse pathologic infiltration of the vertebral body or to access an abnormal lumbar intervertebral disk, allowing for real-time assessment of biopsy needle advancement and potentially reduced procedure time.


a
b
c

6.9 Post-procedure Care

Following image-guided percutaneous lumbar spine biopsy, the patient is transferred to a recovery area and observed and monitored for a minimum of 2 h. During this time, vital signs are recorded, and the biopsy site is examined as per the instructions of the operator. Continued close monitoring is necessary immediately after the procedure to assess for acute complications. Oral or intravenous acetaminophen may be administered for pain relief. If pain is persistent or significant, opiates can be considered. A progressive increase in pain level, however, requires clinical evaluation by the operator. Once stable, the patient can be discharged home with an adult companion, while inpatients can return to their hospital room. Notification of completion of the procedure is to be communicated with the ordering provider. This is especially true of collaborating surgeons, who will need to know the biopsy entry site and pathway, since these are considered contaminated with tumor and may need to be removed at later resection (Davies et al. 1993). The patient should be provided with the appropriate follow-up contact telephone number in case of questions or concerns and should also be instructed to go to emergency room if they experience severe symptoms, such as fever, increasing pain, or bleeding, which are not resolved with conservative measures. A follow-up communication on the day after the procedure is important to ensure that no clinically significant changes have occurred since discharge and to address any patient concerns or questions. The operator or a designated staff member should follow up on all biopsy results to ensure that the sample has been received, tissue or microbiologic diagnosis established, and the appropriate provider(s) notified.

Key Review Points

1. Image-guided lumbar spine biopsy allows sampling of the vertebra, disk, and paraspinal lesions with lower morbidity as compared to open biopsy procedures.
2. The goal of image-guided percutaneous lumbar spine biopsy is to sample the target lesion while avoiding injury to nearby critical anatomic structures.
3. Careful pre-procedure review of all available imaging studies with planning of the patient's position, biopsy approach, and needle trajectory will decrease the procedure time and reduce the likelihood of a complication.
4. Indications for percutaneous lumbar spine biopsy include the evaluation of possible neoplastic or infectious processes in order to establish a diagnosis and guide the patient's clinical management.
5. Complications related to lumbar spine biopsy can be minimized with careful and thorough patient pre-procedure screening and medical optimization, with particular attention to procedure indications and contraindications.
6. Multiple approaches and techniques are available for image-guided percutaneous lumbar spine biopsy depending upon the lesion type, location, and extent.
7. Optimizing diagnostic efficacy can be enhanced with multiple biopsy needle passes, thereby increasing sample size.
8. CT and fluoroscopy can be used for imaging guidance in lumbar spine biopsy procedures, depending on lesion location, size, and extent.

Fig. 6.24 A 63-year-old female with history of breast cancer and low back pain. Frontal and lateral fluoroscopic images (**a**) show the tip of bone biopsy needle (*arrows*) at the junction of the pedicle and posterior vertebral body; the bone needle is temporarily removed in order to dislodge the specimen that has accumulated within the bone needle, into the appropriate container. Frontal and lateral fluoroscopic images (**b**) show advancement of the bone needle (*arrows*); this forward movement again fills the bone needle lumen with additional specimen that is then removed and, in this case, submitted for pathologic analysis. Frontal and lateral fluoroscopic images (**c**) show further advancement of the bone needle (*arrows*) to the anterior and paramedian aspect of the vertebral body in order to obtain additional specimen in this patient with metastatic breast cancer

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