Complications in Musculoskeletal Intervention: Important Considerations

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Abstract

Keywords

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Musculoskeletal (MSK) intervention has proliferated in recent years among various subspecialties in medicine. Despite advancements in image guidance and percutaneous technique, the risk of complication has not been fully eliminated. Overall, complications in MSK interventions are rare, with bleeding and infection the most common encountered. Other complications are even rarer. This article reviews various complications unique to musculoskeletal interventions, assists the reader in understanding where pitfalls lie, and highlights ways to avoid them.

Objectives: Upon completion of this article, the reader will be able to identify various complications of musculoskeletal intervention and ways to avoid them.

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Because of advancements in technology, the prevalence of musculoskeletal procedures performed for either diagnostic or therapeutic indications is increasing and, likewise, the potential for complication has risen. Radiologists and other interventionists alike may find themselves directly involved with a complication as a result of an intervention or indirectly during the interpretation of postprocedure imaging. In this article, the authors discuss various complications of musculoskeletal interventions, describe the underlying risks, and recommend possible steps that can be taken to mitigate these risks.

What Constitutes a Complication?

In the past few years, there has been emphasis placed on quality assurance and the implementation of formal quality assurance programs within practice groups. In the era of Affordable Care, these programs will become critical to streamline efficiency and promote cost containment. Therefore, it is increasingly essential for practice groups to focus on reducing complications by evaluating outcomes of various procedures and implementing strategies to mitigate complications.

To adequately track complications, one must define what constitutes a complication and stratify its severity. The Society of Interventional Radiology (SIR) Classification System for Complications by Outcome is the most widely used classification among interventional radiologists for the reporting of complications and is subdivided into minor and major complications.¹ Minor complications are stratified into complications that require no therapy or are of no consequence; those complications that require nominal therapy and are of no consequence; and those that at most require an overnight admission for observation only. Major complications are stratified into those that require therapy and involve a minor hospitalization (less than 48 hours); those that require major therapy such as an unplanned increase in the level of care or a prolonged hospitalization (greater than 48 hours); those with

permanent adverse sequelae; and those resulting in death. Much like surgical reporting of complications, the SIR classification is inclusive of any complication that occurs within 30 days of a procedure.

In general, the risk of complication from any musculoskeletal intervention depends largely on the type of procedure, the anatomic location, the patient, and the skill of the operator.

Hemorrhage

Since musculoskeletal procedures involve penetration of skin and soft tissues, bleeding is an omnipresent risk. Fortunately, the majority of musculoskeletal procedures rely on relatively small gauge needles, minimizing the risk of serious bleeding.

Knowledge of the anatomy involved with a particular procedure is of utmost importance. Procedures that involve highly vascular tissues, are close to a neurovascular bundle, or are vascular lesions such as renal cell carcinoma metastases or arteriovenous malformations are at increased risk of bleeding. On the other hand, procedures involving hypovascular structures like joints are considered very low risk of bleeding. Ahmed and Gertner reported no difference in bleeding complications in patients with international normalized ratio (INR) above or below 2.0 receiving arthrocentesis and joint injection.²

Besides an understanding of the anatomy, a review of each patient's comorbidities, medications, and coagulation parameters is imperative prior to proceeding with a procedure. Certain conditions such as cirrhosis, chronic liver disease,

vitamin K deficiency, and shock or sepsis with disseminated intravascular coagulation can increase the risk of bleeding. Chronic renal disease can lead to platelet dysfunction, impairing aggregation. Other conditions such as hemophilia and von Willebrand disease predispose patients to bleeding. In addition to these underlying conditions, anticoagulant, antiplatelet, and nonsteroidal anti-inflammatory medications all increase bleeding risk. The practicing interventionalist must continue to educate him- or herself on new anticoagulant and antiplatelet agents. Most importantly, the patient's coagulation profile including prothrombin time/INR, partial thromboplastin time (PTT), and platelet count must be evaluated and any corrections made.

Finally, the experience of the operator plays a large role in the likelihood of bleeding complications. Therefore, the interventionalist must make a careful risk assessment for each patient and procedure, taking into account his or her own ability, and take steps to mitigate risk when possible. Careful review of imaging with the aim of taking vital structures "out of the line of fire" is the most practical strategy in reducing major bleeding complications.

The consequence of hemorrhage in musculoskeletal procedures depends on the location and extent of hemorrhage. Bleeding can range from minimal, controllable at the puncture site, or ecchymoses at the skin, to more significant bleeding with hemothorax, large volume hematoma, or pseudoaneurysm formation (→ **Figs. 1** and **2**).

Hemorrhage in a confined space, such as the calf or thigh, may result in secondary complications such as compartment syndrome.

Fig. 1 A 62-year-old woman with a history of lymphoma and right paraspinal mass. (a) Axial fat suppressed T2 image of the thoracic spine demonstrates a right paraspinal mass at the T9 level (white arrow). (b) Axial image taken during CT-guided biopsy shows biopsy needle in the T9 right paraspinal mass (arrow). (c) Axial contrast-enhanced CT scan obtained 3 days later shows a pseudoaneurysm of the right T9 intercostal artery (white arrow). (d) Angiography demonstrates a small pseudoaneurysm of the right T9 intercostal artery (arrow). (e) Angiography following coil embolization of right T9 intercostal pseudoaneurysm.

Fig. 2 A 58-year-old man with history of right total hip arthroplasty and recurrent dislocation, taking aspirin and clopidogrel, who presented for routine elective hip arthrocentesis. (a) Fluoroscopic image showing placement of an 18-gauge needle in the joint (white arrow). (b) Axial contrast-enhanced CT image of the lower extremities taken in the emergency room a few hours later shows marked swelling of right thigh from large hematoma (patient experienced a 2 gm/dL drop in hemoglobin).

Because numerous variables contribute to hemorrhagic risk, a specific risk cannot always be attributed to any one procedure. While there are no concrete figures to preprocedurally determine hemorrhagic risk, the SIR published in 2012 the SIR Standards of Practice Consensus Guidelines for Periprocedural Management of Coagulation Status and Hemostasis Risk in Percutaneous Image-Guided Interventions. These guidelines, generated by consensus from a committee of 12 experts' evaluation of published data for various procedures, offer a succinct discussion of the risk for both vascular and nonvascular procedures, accounting for patient coagulation status.³ The consensus guidelines stratify various percutaneous procedures into low, moderate, and significant risk of bleeding and offer recommendations with regard to preprocedure laboratory testing and management. An addendum to the initial guideline was published in 2013 with recommendations for additional anticoagulants.⁴

For *low-risk* nonvascular procedures such as superficial aspiration and biopsy (excluding intrathoracic or intraabdominal sites), evaluation of the INR is routinely recommended for patients receiving warfarin or with known or suspected liver disease. An INR of 2.0 is the recommended threshold for treatment with fresh frozen plasma and/or vitamin K. Additionally, evaluation of the PTT is routinely recommended for patients receiving intravenous (IV) unfractionated heparin, though there is no consensus on a threshold for treatment. Routine evaluation of platelet and hematocrit levels is not recommended, but transfusion is recommended for platelet counts below 50,000/ μ L. There is no recommended threshold for transfusion for a low hematocrit. Finally, there is no recommendation to hold aspirin. Withholding one dose of low-molecular-weight heparin prior to a procedure and holding clopidogrel for 5 days prior to a procedure is recommended.⁴

For *moderate-risk* nonvascular procedures such as intra-abdominal, chest wall, or retroperitoneal drainage or biopsy and spine procedures (vertebroplasty, kyphoplasty, lumbar puncture, epidural injection, and facet block), the consensus guidelines recommend routine evaluation of the INR with threshold to correct it to below 1.5. Evaluation of the PTT is

recommended in patients receiving unfractionated heparin, but there is no consensus on treatment, though there is a trend among consensus members for correction of values above 1.5 times that of control. Similar to the low-risk category, there is no recommendation to hold aspirin, but for a transfusion of platelet counts less than 50,000/ μ L, holding one dose of low-molecular-weight heparin and holding clopidogrel for 5 days prior to a procedure are recommended.⁴

For *significant risk* nonvascular procedures such as bone and soft tissue thermal (cryoablation or radiofrequency) ablation, the committee recommends routine evaluation of INR, PTT in patients receiving IV unfractionated heparin, and platelet and hematocrit counts. There is no consensus on routine evaluation of PTT for patients not receiving heparin. The committee recommends treatment of INR levels to below 1.5 times that of control, stopping heparin for PTT levels greater than 1.5 times that of control, and platelet transfusion for platelet levels below 50,000/ μ L. There is no consensus on a threshold for treatment of low hematocrit levels. Withholding clopidogrel and aspirin for 5 days prior to a procedure and low-molecular-weight heparin for 24 hours (up to two doses) is recommended.⁴

A similar approach is suggested by Foremny et al⁵ stratifying musculoskeletal procedures into those cases with low and high bleeding risk. When performing procedures with a low risk of bleeding such as joint injections or aspirations, aspiration of fluid collections (hematomas or abscesses), peritendinous injections, and peripheral nerve blocks, anticoagulation does not need to be held (for INR $\leq$ 3.0). Furthermore, holding clopidogrel is not recommended for these procedures, and platelet count of over 20,000/ μ L are considered adequate. On the other hand, when performing procedures with a high risk of bleeding such as vertebroplasty, vertebral biopsy, and epidural injections, it is recommended that anticoagulation be held for a goal INR of less than 1.5, clopidogrel be held for 5 days, and platelet levels are above 50,000/ μ L. For all procedures except arthrocentesis, these authors recommend holding a single dose of low-molecular-weight heparin prior to anticipated procedures.

Infection

Despite universal precautions and aseptic technique in musculoskeletal intervention, the very small risk of infection remains and infections still occur. Reported rates of infection for different musculoskeletal procedures vary but in general are less than 1%.⁶⁻⁸

It is important to evaluate each patient prior to a musculoskeletal intervention and evaluate him or her for infection risk. Immunocompromised patients such as those with diabetes mellitus or patients receiving chemotherapy, immunosuppressants, and/or radiation are predisposed to infection. Whether immunocompromised or not, active infection elsewhere in the body such as in patients with underlying urinary tract infection or chronic cholecystitis can predispose patients to procedure-related infection. Weingarten et al reported a case of septic arthritis of the left L2-3 facet joint following a therapeutic steroid injection in a woman with a history of urinary retention, recurrent urinary tract infections, intermittent treatment with suppressive antibiotics, and repeated self-catheterization.⁹

For any given procedure, infection risk begins with the patient's own skin flora. Insufficient aseptic skin preparation may allow bacteria to be transmitted from the skin into the deeper tissues during a percutaneous intervention. Depending on the location and depth of the procedure, infection can involve subcutaneous soft tissues, muscle, tendon, joint, and/or bone. Consequences of infection include cellulitis, fasciitis, septic arthritis, septic myositis, septic tenosynovitis, osteomyelitis, meningitis, osteodiscitis, abscess formation, and septicemia.

Strict attention to sterile technique and adherence to universal precautions is an important strategy to prevent infection. Donning of appropriate protective wear including masks, caps, gowns, and sterile gloves will protect the sterile field and the patient, particularly when a procedure is complicated, the procedure time is long, multiple punctures are required, multiple sites are treated, or when there are multiple operators.

Contamination of sterile fields has been studied in the operating room setting and despite sterile technique, glove contamination in the range of 14 to 57% of orthopedic cases has been reported.¹⁰ Moreover, there are reports that there is considerable variability among some interventionalists with regard to the level of aseptic precautions that are taken. In a United Kingdom survey of 100 orthopedists, 100 rheumatologists, and 50 general practitioners, Charalambous et al found that less than 50% of the respondents routinely wore gloves and even fewer (16.8%) used sterile towels to isolate the sterile field when performing ultrasound-guided knee injections. Of note, 24 respondents (12.6%) had encountered septic arthritis after steroid injection of the knee.¹¹ While no specific guidelines exist with regard to the requisite level of aseptic precautions for musculoskeletal procedures, the *SIR* published in 2012 a joint practice guideline for sterile technique during vascular and interventional radiology procedures that addressed clean, clean-contaminated, contaminated, and dirty procedures. Since musculoskeletal procedures are generally considered clean, the guidelines

recommend absolute sterile technique which, at a minimum, would include scrub attire, hair coverings and masks in the presence of open instruments/trays, sterile gowns and gloves for participants, use of sterile drapes allowing for generous coverage of the sterile field, minimization of traffic in the procedure area, and a semirestricted area to serve as a barrier between fully restricted (procedural) and unrestricted areas. The guidelines also discuss cleaning procedures, room turnover, and prevention of cross-infection. Moreover, attire, hand washing, and procedures for gowning and gloving are well detailed in this guideline.¹²

The timing and types of procedures performed in an area may also have implications for sterility. Vollman et al reported three cases of septic arthritis at their institution attributed to contamination from preceding gastrointestinal fluoroscopic studies.¹³

Contamination of procedural equipment and materials represents another avenue for infection. Ultrasound probes, a cornerstone of image-guided musculoskeletal intervention, can act as a potential vector for the transmission of bacteria and viruses. A study from France reported that 3.5% of endovaginal probes were contaminated with human papillomavirus despite low level disinfection and the use of probe covers.¹⁴ Another study found a 22.6% probe contamination rate in their study of 31 probes in their department, despite a standard probe disinfection protocol. These findings suggested a potential transmission of bacteria in one in every four or five patients. Finally, ultrasound gel itself has been reported to be a causative agent for infection when contaminated. A communication from the FDA in 2012 warned of potential infection from ultrasound gel contaminated with *Pseudomonas aeruginosa* and *Klebsiella oxytoca* that was undergoing a recall.¹⁵ Rarely, contamination of injectable material can be a source of infection, as was the case in 2013 when 48 patients died and 720 were treated for persistent fungal infections following epidural spinal injections (ESIs) with contaminated methylprednisolone.^{16,17}

Preprocedural antibiotics are an important consideration when performing musculoskeletal procedures that involve implantation of a foreign material such as polymethylmethacrylate (PMMA) in vertebral augmentation or metal screws during percutaneous fixation. The *SIR* has developed a clinical practice guideline with regard to antibiotic prophylaxis for vascular and interventional procedures which are based on the above-mentioned stratification of procedures as clean, clean-contaminated, contaminated, and dirty.¹⁸ With the exception of percutaneous biopsy and vertebroplasty, the guidelines do not specifically address musculoskeletal procedures. However, since musculoskeletal procedures are generally considered clean, routine prophylaxis would not be recommended with the exception of vertebroplasty. In the case of vertebroplasty, routine prophylaxis is recommended, with the first-line antibiotic agent being IV cefazolin.

A specific caveat in the guidelines regarding percutaneous procedures is for those patients considered high risk, where infected skin or musculoskeletal tissue may be encountered, antibiotics should be selected that provide coverage for *Staphylococcus* and β -hemolytic *Streptococcus* species.

Tumor Seeding

The risk of tract seeding from percutaneous biopsy of bone and soft tissue lesions is extrapolated from the surgical literature, where the rate of local recurrence increased from 7 to 13% in patients who have undergone biopsies without en block resection of the biopsy tract.¹⁹ While there are case reports of recurrent disease involving needle biopsy tracts,^{20,21} the true incidence of tract seeding is not known, and a few authors believe it to be exceedingly rare and doubt the need for tract resection²²; many surgeons, however, continue to excise the biopsy tract. Because of this, understanding compartmental anatomy and engaging in discussion with and guidance from the consultant surgeon are imperative when planning a biopsy to strategically place the biopsy tract and avoid potential seeding of an otherwise disease-free anatomic plane.²³ Tissue planes can act as physical barriers to local growth of a neoplasm; therefore, one should avoid traversing an uninvolved compartment, joint, or neurovascular bundle with a biopsy needle and ensure the needle path is within the anticipated region of resection. The use of a coaxial technique whenever possible is also suggested. A misplaced biopsy tract and the possibility of tract seeding could result in a potentially devastating wider excision than initially planned (including an otherwise unnecessary amputation).

Procedure-Related Fracture

Iatrogenic fractures associated with bone interventions are quite rare. Fractures may occur at the time of the procedure or after. During an intraosseous biopsy or percutaneous screw fixation, fracture could occur during placement of the biopsy device or screw. Gladden and Spill reported an iliac fracture after a bone marrow biopsy, describing it as the first such reported case in the United States.²⁴ The only other reported fracture from a biopsy in the literature was by Bain after reviewing data from the United Kingdom.²⁵ Stellon et al reported one case of an anterior superior iliac spine avulsion that occurred after a transiliac crest bone biopsy.²⁶ In addition, fracture may occur after an intraosseous procedure due to deficiencies in the bone and its inability to handle the stresses exerted on it. Guidance from an orthopedist regarding weight-bearing status after the procedure may help mitigate postprocedure fractures.

Iatrogenic fracture in the setting of vertebral augmentation is also rare. However, the development of subsequent adjacent level fracture following vertebroplasty is not uncommon. Uppin et al reported 22 out of 177 patients (12.4%) treated with vertebroplasty returned with new fractures, with 67% of the new fractures at an adjacent level.²⁷ A meta-analysis by Taylor et al demonstrated 171 new fractures in 1,151 patients treated with kyphoplasty (14.9%) reported over 16 studies, with 64% of the fractures being an adjacent level.²⁸ Some investigators have demonstrated that cement leakage into the intervertebral disk is a significant predictor for the development of subsequent adjacent level fractures.^{29,30} Moon et al showed a correla-

tion between the likelihood of developing a new adjacent level fracture and the amount of PMMA injected during kyphoplasty.³¹

Cement-Related Complications

The use of PMMA for vertebroplasty in the treatment of compression fracture and cementoplasty in the case of underlying bone tumor or insufficiency fracture is not without complication. The worst complication of cement injection is extravasation of cement into the spinal canal during vertebroplasty. The consequences of extravasation depend largely on the location and the amount of cement. Extravasation of cement is fairly common and has been reported to occur in 30 to 65% of patients with osteoporotic vertebral compression fracture and 38 to 73% of patients with malignant collapse.³² Local extravasation of cement into adjacent paravertebral soft tissues is generally well tolerated and is typically of no consequence. Likewise, extravasation into an intervertebral disk is usually not problematic, though as noted earlier it may be associated with greater risk of adjacent level fracture. The incidence of cement leakage into the disk has been reported to be as high as 27.5%.³³

Extravasation into an intervertebral foramen with compression of a nerve root may result in radiculopathy. Further extravasation into the epidural space could result in cord compression necessitating spinal decompression (→ Fig. 3). The incidence of cement leak into the epidural space from percutaneous vertebroplasty has been reported to be 26.5% in one series³⁴ and up to 37.5% in another,³⁵ but if it is in the hands of an experienced operator with good imaging equipment, it should be appreciably lower.

Leak of cement into the paravertebral veins is a frequent occurrence and generally is well tolerated. However, rarely extravasation of cement into veins can embolize to the right heart and ultimately the lungs, with the incidence of asymptomatic pulmonary cement embolism ranging from 2 to 26% of cases³⁶ (→ Fig. 4).

Finally, an especially rare complication is dislodgement of PMMA as a complication of delayed vertebral collapse on the basis of incomplete incorporation following vertebral augmentation.³⁷

Unretrieved Device Fragments

Complications related to retained surgical items such as sponges, surgical ties, suture needles, and other implements have been well described in the surgical literature, and the estimated rate of occurrence is 1 in 8,000 to 18,000 of all inpatient surgeries.³⁸ In the percutaneous arena, retained surgical items are less of a problem than unretrieved device fragments (UDFs). UDFs are a relatively rare occurrence and can be categorized as intravascular, nonvascular, or combined. As one might expect, intravascular UDFs gain more attention because the consequences of a fractured or migrated guidewire, catheter, stent, or vena cava filter in a vessel or the heart can be devastating.³⁹ On the other hand, nonvascular UDFs in musculoskeletal intervention are less

Fig. 3 A 53-year-old woman with metastatic sarcoma to the right sacral ala treated with cementoplasty. (a) Axial CT image during cementoplasty demonstrates needle access (arrow) into a right sacral metastatic lesion. (b) Axial CT image during cementoplasty shows filling of the right sacral ala lesion. (c and d) Axial and coronal images post cementoplasty show extravasation of cement into the S1 neuroforamen abutting the nerve with additional encroachment of the L5 nerve root (black arrows).

prevalent. Given no published data on nonvascular UDFs from musculoskeletal intervention, it is likely an exceedingly rare occurrence, though possibly underreported. Trocars, bone biopsy tools, and bone screws can fail during a procedure and result in a fractured fragment retained in bone or soft tissue. Bain's review of data from bone marrow biopsy morbidity and mortality reported two instances of trephine biopsy needle breakage in a case series of 13,506 procedures. In one case, a trephine biopsy needle broke in the iliac crest requiring surgical retrieval and additional hospitalization. In the other case, the fractured biopsy needle was left in situ.⁴⁰ Huang et al reported on 386 patients prospectively followed

up for complications after computed tomography (CT) guided bone biopsy, and reported one case of a proximal femur biopsy where the cutting needle broke during biopsy but all instruments were removed with no UDFs.⁴¹

Ablation-Related Complications

Musculoskeletal interventionalists using thermal or chemical ablation should be aware of rare but potentially serious complications that stem from ablation of adjacent structures. In addition to the already described potential for hemorrhage, infection, and iatrogenic fracture, certain thermal modalities

Fig. 4 A 60-year-old man treated with L4 and L5 vertebroplasty at an outside hospital. (a and b) Sagittal and coronal CT reformations show extensive intravasation of cement from L4 and L5 vertebroplasties into the inferior vena cava.

such as radiofrequency ablation have the potential for burns. For example, Goetz et al described a patient who experienced a second-degree burn at the grounding pad site.⁴² Nontarget ablation of adjacent neurovascular structures is another potential complication of spinal tumor ablation. Nakatsuka et al reported incomplete hemiplegia in three patients and radiculopathy in one patient with spinal metastases treated with radiofrequency ablation.⁴³ This complication is particularly important given the fact that often the CT and ultrasound appearance of the ablation margin may be difficult to visualize.⁴⁴ Neurologic monitoring or protective measures utilizing CO₂ injection around the nerve root or in the epidural space have been successfully employed to reduce the risk of thermal injury. Peripheral nerve injuries have also been reported in the literature.⁴⁵ Moreover, some targeted osseous lesions in a juxtaepiphyseal location may predispose to cartilage damage on the basis of the ablation zone encompassing subchondral bone and adjacent cartilage, collateral thermal damage, or other unknown mechanisms.⁴⁶ Long-term consequences of these complications may range from early-onset degenerative arthritis to arthrodesis.

Steroid-Related Complications

One of the most ubiquitous agents in the musculoskeletal interventionalists' armamentarium is the use of steroids for diagnostic and therapeutic injection. The safety and efficacy of injectable glucocorticoids are well established, yet rare complications should be recognized. Decreased immune function predisposing to infection is one consideration. Other risks include atrophy of soft tissues including tendons, subcutaneous fat, and skin (with resultant hypopigmentation). Atrophy of tendons can result in tendon rupture and bowstringing,⁴⁷ and atrophy of subcutaneous fat can result in lipodystrophy with cosmetic derangement.⁴⁸ More importantly, systemic toxicity from steroids can result in inhibition of the hypothalamic-pituitary axis lasting up to 2 weeks following a single injection.⁴⁹ Acute adrenal crisis has been reported in a patient after intra-articular injection⁵⁰; additionally, steroids can produce hyperglycemia in patients with diabetes following joint injection.⁵¹ Repeated injections should be performed with care, and it may be advisable to extrapolate from recommendations advocated by some authors for limiting steroids in ESIs to an annual dose of 3 mg/kg of triamcinolone or its equivalent.⁵²

Image guidance is indispensable in the performance of steroid injections. A study in 1993 by Jones et al reported that one-third to nearly one-half of blind (nonimage guided) joint injections were extra-articular.⁵³ This has considerable implications for treatment if subsequent surgical intervention depends on the outcome of the diagnostic injection. Furthermore, nontarget injection of surrounding structures can result in significant disability, such as with carpal tunnel injections resulting in injury to the median nerve.⁵⁴

Caution must also be exercised in the use of steroids in the spine even with image guidance. While image guidance is useful in guiding needles into the epidural space, finesse is required when directing the needle through the ligamentum

flavum, a relatively thick and dense structure with a definite difference in transneedle tactile sensation compared with the skin, overlying subcutaneous fat, and paraspinal musculature, which cannot be taught and is learned only through practice. Without the tactile sense to assist in guidance, the risk of intrathecal injection is increased, the consequences of which can result in adhesive arachnoiditis, sclerosing pachymeningitis, and calcific arachnoiditis. The incidence of transdural puncture is estimated to occur in 5 to 6% of epidural injections, and postpuncture dural headache is a known complication reported to occur in 1.4 to 6% of ESIs.⁵⁵

Fig. 5 A 39-year-old obese woman with a history of acute myelogenous leukemia, BMI of 35, and multiple previous bone marrow biopsies performed without image guidance. One previous biopsy (prior to this CT) resulted in return of clear fluid later determined to be cerebrospinal fluid. (a–c) Axial CT images through the pelvis show biopsy tracts (black arrows) through the posterior elements of the sacrum, including one tract into the spinal canal.

Rare but devastating neurological complications have been reported associated with ESI, including cerebral and cord infarction, paraplegia, and death.⁵⁶ While no one mechanism has been identified, several mechanisms have been proposed,^{57,58} of which the most discussed is the theory that particulate steroids used in ESI may act as embolic agents causing occlusion of a radicular artery, namely, the artery of Adamkiewicz, with resultant spinal cord ischemia.

Intrathecal injection of anesthetics and nonionic contrast coadministered with steroids also present unique problems. The safe use of intrathecal contrast for myelography has been accepted for years; however, it is important to note that nonionic iso-osmolar or hypo-osmolar contrast agents should be used and therefore are the recommended agents for ESI. On the other hand, intradural injection of

anesthetics should be avoided as transient motor weakness and paralysis could occur. Any violation of the dura during ESI should result in discontinuation of the procedure at that level.

Biopsy-Related Complications

Imaged-guided percutaneous core biopsy has become an accepted and accurate means to diagnose osseous and soft tissue musculoskeletal lesions.^{59–61} Diagnostic accuracy rates of up to 97% have been reported.⁶¹ Moreover, one study even also reported that open biopsy offered limited additional information over a preceding percutaneous biopsy, with many of these tumors even difficult to characterize at the time of final resection.⁶²

Fig. 6 A 70-year-old man with an osteolytic lesion in the right ilium. (a) CT guided biopsy performed following this CT (b) yielded necrotic tissue with hyalinization. Subsequent MRI shows the original biopsy to be in an area of necrosis/nonenhancement; T2 with fat saturation (c) and dynamic post contrast FAME (d) with a corresponding subtraction image (e). Additional post contrast dynamic FAME (f) and corresponding subtraction image (g) from a more inferior location in the tumor demonstrates more uniform enhancement of the tumor in this location. Subsequent CT-guided biopsy targeting this area of enhancement (h) was positive for plasma cell myeloma.

Image-guided biopsy has advantages over both palpation-guided percutaneous biopsy and open surgical biopsy. Under image guidance, a target lesion is identified, typically using CT or ultrasound, and the biopsy device is directly observed traversing and sampling the target area. Using imaging guidance, one can confirm that the biopsy is from the area of interest, and that adjacent vital structures are not violated, that cannot be confirmed with a palpation-guided biopsy. In addition, most image-guided biopsies are performed with only local anesthesia or local anesthesia and conscious sedation (IV midazolam and fentanyl), eliminating the need for general anesthesia that may be necessary with a surgical biopsy. Also, image-guided biopsies are performed with a small caliber needle (often 8–18 gauge) through a small skin nick, eliminating the need for larger incisions and suture closure. When the musculoskeletal interventionalist employs these techniques, most patients undergoing image-guided percutaneous biopsy are able to leave the department immediately or within an hour of procedure completion, and often experience low morbidity. Additionally, the cost of percutaneous biopsy is typically less than open surgical biopsy (► Fig. 5).

While image-guided percutaneous biopsy has several advantages, there are a few pitfalls to consider in addition to the more common risks of musculoskeletal intervention (i.e., bleeding, infection, fracture). Sampling error and non-diagnostic biopsy are the most common pitfalls because only small fragments of the target lesion are removed for pathologic analysis. Since only a portion of the tumor is sampled, more aggressive cells may not be included in the biopsy specimen. To avoid sampling error, it is advisable when possible that the biopsy device be moved to different areas within a lesion, via the same skin entry site, to obtain samples from multiple areas. The most common reason for a non-diagnostic biopsy is the unintended sampling of areas of tumor necrosis resulting in biopsy samples showing only nonviable cells. To avoid a nondiagnostic biopsy, prebiopsy imaging should be reviewed with attention to dynamic postcontrast magnetic resonance images. Targeting areas of enhancement at the time of biopsy may improve diagnostic yield (► Fig. 6).

Conclusion

Fortunately, complications in musculoskeletal intervention are rare. Image guidance can help minimize the risk of misadventure with injury to adjacent structures. Ultimately, it is the responsibility of the musculoskeletal interventionalist to tailor any given procedure to a patient's specific anatomy and comorbidities. Not surprisingly, hemorrhage and infection are the most common complications that can occur, but with proper planning and precautions the consequences of such complications can be minimized. Other complications in musculoskeletal intervention such as fracture, UDFs, and tumor seeding are even less common but can have more serious consequences if unrecognized. It is imperative for interventionalists to maintain vigilance when performing musculoskeletal procedures and not be lulled into

false sense of security simply because of the relative ease of the percutaneous approach.

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