Surgical Management of Metastatic Long Bone Fractures: Principles and Techniques

Abstract

Management of metastatic long bone fractures requires identification of the lesion and the use of sound fracture fixation principles to relieve pain and restore function. The treating surgeon must understand the principles of pathologic fracture fixation before initiating treatment. Because these fractures occur in the context of a progressive systemic disease, management typically involves a multidisciplinary approach. When considering surgical stabilization of these fractures, the abnormal (or absent) healing environment associated with diseased bone and the overall condition of the patient must be taken into account. The goal of surgery is to obtain a rigid mechanical construct, which allows for early mobility and weight bearing. This can be achieved using internal fixation with polymethyl methacrylate cement or segmental resection and joint reconstruction. Prosthetic joint arthroplasty is a more reliable means of fracture management when insufficient bone is present for fixation. Prophylactic stabilization of impending pathologic fractures can reduce the morbidity associated with metastatic lesions.

Management of pathologic long bone fractures differs from that of fractures of disease-free bone. The primary surgical goal is restoration of anatomic limb length, alignment, and rotation by creating a stable construct that allows early motion and weight bearing. Unlike tumor-free bone, pathologic fractures typically occur in the setting of a progressive systemic disease that affects not only the injured bone, but also the patient’s ability to undergo surgery. Pathologic fracture ends may respond with very limited healing. Because diseased bone has a deficient healing response, strategies are frequently used to improve fixation. For example, polymethyl methacrylate (PMMA) cement frequently is used in and around the fracture site to provide the immediate and lasting stability required for pain-free use of the limb.

Management of a pathologic long bone fracture requires consideration of the patient’s overall medical condition as well as the acute injury. Frequently, patients with these injuries are being treated with chemotherapy or radiotherapy in the perioperative period, which affects the body’s ability to respond to the physiologic stress of a fracture, the procedure, and postoperative recovery. In all patients with pathologic long bone fractures, surgical stabilization should be considered regardless of life expectancy or prognosis. Pathologic fractures of the humerus may be amenable to nonsurgical management in a patient with limited life ex-
pectancy; however, fractures in the lower extremity should be managed to restore mobility and improve the remaining quality of life.

Identification and diagnosis of an osseous lesion is crucial for successful management of a pathologic fracture. Because care of patients with metastatic cancer has improved overall, the number of metastatic bone lesions and pathologic fractures seen by orthopaedic oncologists and general orthopaedists has increased.\(^2\) Initiation of treatment without first identifying the pathologic process can result in significant patient morbidity.\(^3,4\) Proper identification of this process and care of the patient with a pathologic fracture often require a multidisciplinary team of healthcare providers, including pathologists and radiologists familiar with orthopaedic oncologic diagnoses and interventional radiologists who can perform image-guided biopsies or directed arterial embolizations. Radiation and medical oncologists coordinate additional treatment regimens to address the primary disease process and improve patient survival. Care of these patients involves not only accurate diagnosis of the pathologic process and surgical stabilization of the fracture, but also collaboration with a multidisciplinary team of physicians.

### Diagnosis

Patient workup must be thorough and appropriate for the clinical context. If a definitive diagnosis cannot be made based on a thorough history, physical examination, laboratory tests, and radiographic evaluation, a biopsy should be performed and a histologic diagnosis must be made before fracture fixation. In patients who have a history of cancer (even previous metastatic bone disease), a newly diagnosed osseous lesion cannot be assumed to be part of the same pathologic process.

Adams et al\(^4\) reported on complications associated with misdiagnosis of an osseous lesion. Eight patients underwent internal fixation for a lesion that was assumed to be metastatic and was later found to be a primary bone tumor. The authors concluded that misdiagnosis was the result of incomplete patient history and radiographic evaluation as well as improper surgical biopsy techniques (including histopathologic interpretation). They also found that treatment modalities violated compartmental boundaries. Therefore, a planned surgical biopsy should be performed if the skeletal lesion does not demonstrate clinical and radiographic characteristics consistent with the known tumor process.

### History and Physical Examination

The first step in management of a fracture through a metastatic lesion is recognition that a pathologic process exists in the setting of an acute fracture. Therefore, the use of an organized and systematic approach is required when evaluating a patient with a carcinoma of unknown origin.\(^5,6\) A complete history and physical examination must be performed. When possible, the history should be obtained from the patient and should include a complete review of systems and relevant family history, especially if the primary lesion is of unknown origin. The physical examination should focus on the affected extremity as well as identification of abnormalities such as regional lymphadenopathy or nodules within the thyroid, prostate (in men), or breast (in women).

### Laboratory Studies

Basic laboratory studies are useful for evaluating the patient’s overall medical condition, identifying certain primary tumors, and excluding a diagnosis of multiple myeloma. A complete blood count with differential and a basic metabolic panel, including liver and renal function tests, should be obtained. Specific tumor markers can help to identify a metastatic process (eg, prostate specific antigen in prostate cancer) or a specific disease (eg, monoclonal antibodies in serum, urine immunoelectrophoresis in multiple myeloma). The patient’s blood should be typed and cross-matched for blood products if a surgical procedure is anticipated; the risk of bleeding may be considerable in the setting of some pathologic processes (eg, renal cell carcinoma, multiple myeloma) and is somewhat unpredictable.

### Radiographic Evaluation

Orthogonal plain radiographs of the affected limb and the joint above and below the area of interest and a plain radiograph of the chest are obtained to evaluate a pathologic lesion or fracture secondary to an unknown primary carcinoma. The orthopaedic surgeon must always consider that a lesion is present when evaluating the initial radiograph of the fracture, especially in the setting of abnormal bone. CT and positron emission tomography–CT of the chest, abdomen, and pelvis are obtained for diagnostic and staging purposes. CT of the area of interest can help to define whether the lesion is contained, with intact cortical boundaries, or uncontained, extending outside bone and into the surrounding soft tissues. Advanced imaging modalities, such as bone scintigraphy, are used to identify other skeletal lesions. Occasionally, MRI can aid the evaluation of the soft tissues surrounding a pathologic fracture, but this is not routine or necessary. The radiographic workup for each patient reflects the...
The literature supports the use of percutaneous biopsy techniques, although not specifically in the setting of a fracture. Retrospective studies have reported that core needle biopsies performed in the office have an accuracy rate >80%. Advantages of percutaneous techniques include decreased soft-tissue contamination, minimal anesthesia requirement, and decreased procedural cost. In certain anatomic locations, such as the pelvis and spine, CT- and ultrasound-guided percutaneous biopsy can be used. The drawback of these procedures is that often only a small amount of tissue is obtained, which can result in normal or nondiagnostic findings. Errors in diagnosis can also be made if the tissue sample is heterogeneous or if the operator is not sampling directly from the area of interest. Therefore, the decision to proceed with open or percutaneous biopsy is dependent on the preference and practice of the surgeon as well as the available institutional staff and resources. Regardless of the technique used, if the pathologist or surgeon is unsure whether lesional tissue represents a sarcoma, fixation should be delayed until a definitive diagnosis is made.

**Management**

Most metastatic long bone fractures encountered by the orthopaedic surgeon occur as a result of metastasis from carcinomas of the breast, lung, and kidney or multiple myeloma. Most metastatic lesions caused by prostate cancer are blastic and rarely fracture; lytic prostate metastases do occur and behave in a fashion similar to that of other lytic metastatic lesions. The surgeon must understand that pathologic bone does not respond to conventional fixation constructs in the same manner as nonpathologic bone, and a normal healing response cannot be expected. Therefore, surgical management of pathologic fractures requires the use of fixation techniques and strategies that account for the abnormal healing response.

When plate and screw fixation is performed, plates of appropriate size and length must be selected and applied correctly. If joint reconstruction is performed, lesion resection must be complete and arthroplasty components must be sized to allow immediate mobility and decrease the risk of periprosthetic fracture. When appropriate, PMMA bone cement should be used to increase the stability imparted by the fixation construct.

**Preoperative Planning**

Preoperative planning is crucial for surgical management of any fracture. Many patients who present with a metastatic long bone fracture have other medical issues that can complicate a surgical procedure. Excessive bleeding from a tumor, poor-quality bone or soft-tissue envelope, altered anatomy, spread of tumor, and the patient’s inability to tolerate a long period of anesthesia are some factors that can alter a surgical procedure. Therefore, anticipation of these factors and creation of an alternate plan or plans are essential. The primary surgical plan and other potential surgical possibilities must be communicated to all members of the multidisciplinary team.

**Plate and Screw Fixation**

Management of a pathologic fracture with open reduction and internal fixation (ORIF) permits curettage of the pathologic lesion and, if necessary, application of bone cement to improve construct stability (Figure 1). The location of the fracture, quality of the adjacent host bone, and size of any remaining osseous defect after
lesion curettage or resection determine whether a nonlocking or locking plate is selected for fracture fixation. Compared with nonlocking fixation, locking plates provide improved fixation in the setting of poor bone quality, and a locked fixed-angle construct decreases screw pullout.10 Locking plates have been used successfully for fixation of specific fractures (eg, proximal humerus, distal femur, distal radius), especially in the setting of poor (nonpathologic) bone stock, leading to an increased use of these devices in orthopaedic tumor surgery, particularly when intramedullary (IM) nail fixation is not appropriate. Several retrospective studies have reported on the use of locking plates for management of pathologic lesions and fractures; however, additional research is needed to further define the indications for the use of these devices.11-13

Intramedullary Nailing

IM nail fixation is a safe and effective method for treating patients with pathologic long bone fractures or a risk of impending fracture.14 Once the lesion has been identified, IM nailing can be performed with or without the use of a supplemental open incision or cement. Unlike nonpathologic bone, cortical discontinuity present in pathologic bone after IM nailing may never heal and may result in continued pain and disability that often is improved with supplemental use of cement.15 Femoral nails can be placed antegrade or retrograde. With antegrade placement, proximal interlocking screws can be used to obtain purchase into the femoral neck and head, increasing proximal nail fixation. The use of a short nail that does not span the entire length of the femur is not recommended.16 Short IM nails leave unnecessary stress risers and do not protect the length of the long bone, placing the affected extremity at risk for later peri-implant fracture. Diaphyseal humeral lesions that do not involve the proximal or distal articular segments of the bone are frequently managed with IM nailing17 (Figure 2). Tibial fractures with isolated lesions also can be managed with this technique, although the tibia is not affected by metastatic disease as often as the spine, femur, and humerus.18

Megaprostheses

Conventional or segmental prostheses often allow immediate weight bearing in addition to immediate restoration of limb length and stability.19 Currently, many segmental prostheses are modular and can be assembled to fit the anatomy of each patient. These “tumor prostheses” are used frequently in the hip, knee, and shoulder joints. Occasionally, intercalary prostheses are used in the humerus and femur when the proximal and distal articular block is not involved in the pathologic process. Frequently, these prostheses are implanted using cement, which imparts immediate stability, and do not rely on bony ingrowth.

Several factors must be considered when these implants are used. The surrounding muscular attachments are reattached or reapproximated to the prosthesis (eg, rotator cuff and tuberosities, hip abductors/external...
rotators and greater trochanter). However, a deficit of functional strength or range of motion may occur. In some scenarios, particularly following prosthetic hip/proximal femoral arthroplasty, joint stability can be compromised if there is significant soft-tissue disruption, placing these patients at risk of dislocation. When possible, repair of the hip capsule and reattachment of the hip abductors and hip external rotators should be performed to increase joint stability. As with any procedure, postoperative infection and revision surgery can result in notable patient morbidity.

**Cement and Bone Graft**

The adjunctive use of PMMA cement for fixation of pathologic fractures is well established. This cement is used to fill an osseous void after curettage or resection of a pathologic lesion; it provides immediate stability to the fixation construct. Axial and rotational stability are improved with the addition of cement to a fixation construct. One study showed that postoperative pain and function improved with the use of PMMA cement in fixation of pathologic fractures. Cement can be used with plate fixation or can be placed around an IM nail to restore cortical continuity (Figure 3). In addition, antibiotics can be incorporated into the PMMA cement for elution. However, nothing in the literature supports the prophylactic addition of antibiotics to bone cement used for fixation of pathologic fractures. Interestingly, the addition of cytotoxic tumor drugs to PMMA cement to decrease both the local recurrence and development of additional metastatic lesions has been investigated. Thus, in addition to its structural properties, PMMA can be used, at least theoretically, as a drug delivery vehicle.

The use of cement has been shown to improve the pullout strength of orthopaedic screws. This technique can be used when bone quality is suboptimal, especially around the fracture. For plate fixation, locking or nonlocking screws can be inserted through bone cement after the intended screw path is carefully predrilled and tapped, if necessary. Cement augmentation of IM nail fixation requires that the nail and interlocking screws be placed before any cement is used and allowed to set.

Nonstructural cancellous allograft bone has been used in fixation of pathologic fractures, but it provides little mechanical support to the fixation construct and relies on bone that has limited healing potential. Free vascularized autograft has been used in complex limb reconstruction following failed fixation of pathologic fractures. The use of orthobiologics (eg, calcium phosphate, calcium sulfate) in patients with metastatic long bone fractures has not been studied; therefore, orthobiologics currently do not have a role in management of pathologic fractures.

**Fixation Strategies By Fracture Site**

**Humerus**

Pathologic lesions occur frequently in the humerus. Some fractures, especially those in the proximal humerus, are amenable to nonsurgical management if the fracture is incomplete or minimally displaced. Most complete or displaced fractures require surgical intervention (Figure 4). For pathologic fractures of the proximal humerus, plate fixation or endo-
prosthetic replacement is used, based on the extent of bone involved. If doubt exists regarding the reliability of fixation of the proximal segment (even with cement), a cemented prosthesis should be used. In the setting of proximal or humeral head fractures, attenuation of the rotator cuff muscles often has occurred; thus, surgical goals focus on maintaining glenohumeral stability and providing pain relief.

In fractures of the humeral diaphysis, deforming forces are often torsional but can also be compressive if patients use crutches or assistive devices. These fractures can be addressed with antegrade or retrograde IM nailing or ORIF and are frequently augmented with cement. IM nail placement can be performed using an open or closed technique depending on whether the pathologic bone will be addressed, cement will be used, and the radial nerve will be identified and protected. IM nailing of pathologic fractures of the humeral diaphysis is recommended for fractures that occur in an area that begins 2 to 3 cm distal to the greater tuberosity to 5 cm proximal to the olecranon fossa. Stable fixation can be difficult to achieve in the distal aspect of the humerus because of the shape and quality of the bone. An increased rate of construct failure has been reported in the setting of a pathologic lesion. In this anatomic area, IM nailing does not provide adequate stability, and dual plate fixation with cement is often necessary. In some cases, a total elbow prosthesis should be considered if fracture fixation is unreliable.

**Hip and Femur**

Pathologic proximal femoral fractures cause substantial morbidity in patients with skeletal metastases. Management of proximal femoral fractures is often based on factors such as cancer type, the patient’s life expectancy, fracture displacement, and the anatomic region involved. These fractures can be managed with many different methods, including IM nailing, ORIF, and endoprosthetic reconstruction (Figure 5). Cement is frequently used in IM nailing and ORIF. Pathologic lesions in the femoral head and neck have poor healing potential. Fracture fixation at this site is rarely indicated. Hip hemiarthroplasty or total hip arthroplasty is indicated, however. The use of femoral endoprostheses (often cemented) is preferred if no acetabular pathology is present (Figure 6, A).

Uncemented total hip arthroplasty components have been used in patients with metastatic disease of the hip; however, this is not the senior author’s (R.D.L.) preferred technique. Intertrochanteric and subtrochanteric fractures are subject to the same deforming forces as nonpathologic bone, and management should
Treatment algorithm for metastatic fractures of the femur. IM = intramedullary, PMMA = polymethyl methacrylate.
be determined by the factors mentioned previously. Fractures amenable to fixation with an IM device often require fixation that extends to the proximal femoral head and neck in addition to cement augmentation (Figure 6, B). Full-length IM nails are used to protect the entire femur and prevent creation of a stress riser. The use of a long implant also protects against recurrent metastatic lesions and the effects of postoperative radiation, such as osteonecrosis and osteopenia. Recent literature has suggested that the use of an endoprosthesis to manage proximal femur fractures may yield better long-term results than IM nailing or ORIF.

In fractures of the femoral diaphysis, axial weight bearing and rotational torque are the primary deforming forces; fixation with an IM nail that spans the entire length of the bone is typically preferred. For fractures of the mid or distal femur, a retrograde nail can be used, but insertion may violate the knee joint; therefore, this option is often avoided. For distal diaphyseal and metadiaphyseal fractures of the femur, lateral locking plate fixation with lesion curettage and PMMA augmentation provides reliable fixation.

**Tibia**

Metastatic lesions to the tibia are rare and should be treated using the same principles as those for lesions of the humerus and femur. If the lesion involves a substantial portion of the proximal third of the tibia and fracture fixation will not result in a reliable construct, a cemented segmental endoprosthesis should be used (Figure 7). In many cases, an anterograde interlocking tibial nail can be used to manage a fracture anywhere from the proximal metaphyseal region to the distal metaphysis. Development of new tibial nails that have more interlocking options has resulted in increased use of these nails for fractures of the distal tibia. Locking plates designed specifically for the proximal and distal tibia can be used as an alternative to nail fixation. The tibial soft-tissue envelope is not as robust as that of the femur or humerus, especially at the anteromedial aspect of the tibia. Therefore, a surgical incision or placement of a surface implant, such as a plate and screw device, in this location may not be as desirable as the use of an IM implant. When pathologic fracture fixation cannot be performed in the distal tibia due to intra-articular extension or bone loss, limb salvage versus amputation must be discussed with the patient.

**Management of Impending Fractures**

In patients with metastatic skeletal lesions, surgical fixation is warranted if there is a risk of fracture through the affected area with physiologic loading. The radiographic appearance of the lesion and the patient’s symptoms help the physician to decide whether prophylactic treatment is necessary. Historically, the criteria for risk of fracture included cortical destruction >50% or absolute lesion size >2.5 cm. Mirels developed a scoring system using several factors to determine whether a pathologic lesion requires surgical stabilization or can be managed with radiotherapy (Table 2). The scoring system is based on the presence or absence of pain and the size, location, and radiographic appearance of the lesion. Each variable is given a value between 1 and 3. The author concluded that lesions with a score ≤7 could be managed with irradiation alone, whereas lesions with a score ≥9 required prophylactic fixation before irradiation. This scoring system is best used as a guide because a patient’s pain and disability frequently dictate the decision to manage a skeletal lesion with prophylactic fixation. In the senior author’s (R.D.L.) experience, mechanical pain requires close scrutiny and is nearly always an indication of an impending fracture; the surgeon should maintain a low threshold for surgical fixation.

Prophylactic fixation of skeletal lesions has been shown to relieve pain, shorten overall length of hospitalization, and improve survival. Fixation of impending fractures is based on the same principles as those used for...
for fixation of displaced pathologic fractures. When possible, bone cement should be used to fill lesional voids. Fixation constructs that allow immediate weight bearing and mobilization, without concern for further injury, should be used. Drawbacks of prophylactic fixation include the potential risk of perioperative and postoperative medical and surgical complications. Ultimately, the surgeon must weigh these factors against the potential benefits to the patient before deciding to proceed with surgery.

**Summary**

Management of metastatic long bone fractures requires an accurate diagnosis of the lesion before fixation is performed. The orthopaedic surgeon must understand that the healing environment of the fracture site is altered in patients with metastatic fractures. The surgical fixation plan must involve meticulous care of the soft tissues (Table 1). PMMA bone cement can be used as an adjunct to enhance the stability of a fixation construct in the setting of pathologic bone. When stable fixation cannot be achieved or notable periarticular tumor involvement exists, joint arthroplasty prostheses can be used. The overall care of cancer patients, including those with metastatic long bone fractures and/or impending fractures has improved the success of surgical intervention and improved the survival of these patients.²

**References**

*Evidence-based Medicine: Levels of evidence are described in the table of contents. In this article, references 5, 7, and 9 are level II studies. References 8, 13, 15, and 35-37 are level III*
studies. References 1, 3, 4, 11, 12, 14, 17, 19-21, 27, 28, 30, 31, 34, and 38 are level IV studies. Reference 6 is level V expert opinion.

References printed in bold type are those published within the past 5 years.

