Surgical intervention is effective in many patients with nonvertebral osseous metastasis.

Surgical Intervention of Nonvertebral Osseous Metastasis

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Background: Nonvertebral osseous metastases can result in pain and disability. The goals of surgical intervention are to reduce pain and to improve function if nonsurgical treatment fails. The indications for proceeding with surgical intervention depend on anatomic location, amount of local destruction, extent of skeletal and visceral disease and, most important, the patient’s performance status and life expectancy.

Methods: This article reviews the evaluation and treatment of metastatic nonvertebral osseous lesions from the perspective of the orthopedic surgeon, based mainly on an assessment of the surgical literature.

Results: This article summarizes the approaches to preoperative evaluation, patient selection, and medical optimization. Guidelines for estimating osseous stability and fracture risk are discussed, and surgical implants and their relation to postoperative outcomes are examined. This review also describes less invasive ablative procedures currently available.

Conclusions: The surgical management of nonvertebral osseous metastases involves multidisciplinary collaboration. The surgical construct must be a stable, reliable, and durable intervention that is individually tailored and matched to a patient’s prognosis and performance status.

Introduction

Metastatic bone disease can cause significant pain and disability. Though the spine is the most common site, osseous lesions of the pelvis and the extremities frequently occur as well. The patient with the nonvertebral osseous metastasis should be approached systematically with a history and an examination, as well as the appropriate staging and imaging studies. The diagnosis of metastatic disease must be established before proceeding with treatment. Asymptomatic lesions can be observed and followed. The nonoperative treatment options for a symptomatic lesion involve analgesics, bracing, radiation, and systemic therapy, in addition to interventional ablative procedures for pain control and palliation. If a lesion has fractured or is likely to fracture in spite of nonoperative treatment, the surgical options must be tailored to the individual patient. The goals of surgical intervention are to relieve pain, improve function, and restore mobilization and ambulation. The surgical construct must be stable enough to allow immediate weight-bearing and be durable enough to function through the patient’s lifetime. This article reviews the surgical indications and considerations and the operative management of nonvertebral metastatic lesions.
Evaluation and Diagnosis

Patients with a symptomatic osseous lesion will report pain as the most common symptom. A thorough history detailing the characterization, location, onset, and duration of the pain should be elicited. Pain that resolves with rest is often attributed to a muscular strain or sprain. Mechanical weight-bearing pain that does not resolve with rest is of concern for a more ominous process, such as an impending pathological fracture. This suggests that the remaining host bone can no longer withstand normal physiologic forces. A history of cancer with active metastatic skeletal disease elsewhere can help to narrow the differential.

A thorough physical examination should be performed with an emphasis on the involved extremity. Visual inspection of the extremity may reveal areas of swelling, ulceration, or deformity. Palpation will elicit any focal tenderness or crepitus. The passive and active motion of each joint should be documented with regard to range of motion and to any positions that cause pain. The neurologic and vascular status of the extremity must also be examined to find any motor, sensory, or perfusion deficit. A documented baseline neurovascular examination is especially essential if an operation on the involved extremity is planned.

The radiographic diagnosis of an osseous lesion begins with a plain film. The description and examination of a lesion should be organized and systematic, addressing three main questions. First, where is the lesion within the involved bone: proximal or distal, metaphysis or diaphysis, or on the articular surface? Next, how distinct are the borders between the lesion and the native bone (ie, is the lesion well marginated or poorly marginated)? Finally, are there any internal features that characterize the lesion, such as zones of sclerosis, lucency, or calcific or ossific densities? Other features of concern include cortical destruction, periosteal reaction, and discrete fracture lines.

In the patient with an established histologic diagnosis of a primary carcinoma with known visceral and skeletal metastatic disease seen on staging studies, it can be assumed that a destructive osseous lesion is metastatic in origin as well. One can then proceed as is standard in the evaluation and management of metastatic skeletal disease.

Caution is needed when evaluating the solitary, isolated bone lesion in an adult, even if there is a history of carcinoma. In this scenario, the presumed diagnosis is metastatic carcinoma of an unknown primary; however, the differential diagnosis should also include myeloma, lymphoma, primary sarcoma, and infection. The staging workup in these cases has been well described and begins with a history, an examination, and appropriate laboratory tests. These tests include a metabolic panel a blood count, serum protein electrophoresis (SPEP), serum calcium, prostate-specific antigen, C-reactive protein, and erythrocyte sedimentation rate. Radiographic staging includes at least two plain films of the entire long bone: chest radiographs, a whole-body bone scan, and computed tomography (CT) scans of the chest, abdomen, and pelvis, each with oral and intravenous contrast. On the basis of the above results, one can then proceed with a needle or an incisional biopsy in order to establish a pathological tissue diagnosis before embarking on medical, surgical, or radiation management.

Previous studies have reported that this diagnostic strategy identified the primary site of carcinoma in 85% of patients. Moreover, completion of diagnostic staging prior to biopsy is recommended for the following reasons:

- If the lesion is a sarcoma, an inappropriate biopsy may compromise future limb salvage. Another site may be found that is easier and more accessible to biopsy.
- If a renal cell carcinoma is suspected, preoperative embolization may be utilized to minimize blood loss.
- A positive SPEP test may preclude the need for an invasive biopsy.
- An open incisional biopsy is sometimes performed just prior to the fixation or reconstruction of a pathological fracture. Having found a primary site of malignancy on staging studies, the pathologist can be more confident with a histologic diagnosis based on an intraoperative frozen section. This will allow the surgeon to extend the incision and dissection and proceed with fixation or reconstruction of a pathological fracture. Biopsy of the lesion and stabilization of the fracture can thus be performed in a single operative setting, thereby obviating the need for another operation.

This strategy will avoid the inadvertent and devastating consequences of violating a sarcoma and contaminating the operative field, otherwise known as rodding a sarcoma; placing internal fixation across a bone sarcoma presumed to be a metastasis will contaminate all involved incisions and planes of dissection. This setting complicates future surgical management and may lead to a more morbid surgical procedure such as an amputation.

Evaluation of Mechanical Stability

Evaluation of osseous stability is challenging even for the experienced surgeon. Plain radiographs provide the most insight into the structural integrity of bone. CT scans will define cortical architecture in more de-
tail. Magnetic resonance imaging (MRI) scans will show the intramedullary extent of tumor and any soft-tissue extension. However, CT and MRI scans will magnify the extent of osseous disease seen on plain radiographs and will exaggerate the risk of fracture. Most of the studies that have provided classic guidelines for predicting impending pathological fractures and the indications for prophylactic fixation have relied on plain radiographs. Orthopedic surgeons therefore place most weight on plain films when evaluating the mechanical stability of bone.

Although no absolute guidelines exist, a number of studies have provided criteria to support clinical judgment and radiographic interpretation. In 1973, Fidler suggested that a long bone lesion with more than 50% cortical destruction should be prophylactically stabilized. In 1982, Harrington reviewed the literature and summarized the trends at that time of indications considered for prophylactic stabilization of the femur, which included (1) a lesion ≥ 2.5 cm, (2) a lesion with > 50% cortical destruction, and (3) a lesion causing persistent pain after a trial of radiation therapy.

In 1989, Mirels developed a scoring system to predict the risk of impending fracture in long bones. Results were based on a retrospective analysis of plain films, primarily in patients with metastatic breast carcinoma. Four criteria were analyzed, with a maximum of 12 points, based on lesion site, size, degree of sclerosis/lysis, and pain. Though these are not categorical or absolute criteria, subsequent studies have validated this system as having high sensitivity but low specificity.

In other words, at the very least, this scoring system provides a relative framework whereby orthopedic surgeons can support clinical decisions based on plain film interpretation.

Current and future projects involve the use of more advanced imaging to predict fracture risk based on quantitative structural analysis. For example, CT-based structural rigidity analysis has been investigated to quantify mechanical stability in children with benign bone tumors. Axial images of an osseous lesion can be compared to normal contralateral bone and then used to calculate the axial, bending, and torsional rigidity of an osseous lesion. This potentially can provide the clinician with a quantifiable risk for fracture.

Hong et al similarly applied these algorithms to quantitative CT, MRI, and dual-energy x-ray absorptiometry in order to estimate the relative fracture risk of trabecular defects in vertebral bodies. Keyak et al employed CT-based finite element modeling to quantify the strength and stability of femoral shafts with and without metastatic lesions as a means to predict the risk of pathological fracture. However, practical application of these noninvasive advanced imaging techniques has not yet been established, and they have not yet replaced clinical judgment and plain film interpretation.

Surgical Indications
The indications for surgery vary among patients and surgeons. However, most physicians agree that the decision to proceed with surgery is based on a variety of factors, including severity of symptoms, location of tumor, expected morbidity if a fracture were to occur, expectations of the patient, and viability of alternative or adjuvant treatments. The surgical goal is to decrease pain and improve mobility, function, and quality of life. The patient must be medically fit for surgery, and the recovery and rehabilitation phase should not exceed the patient’s life expectancy. Moreover, the surgical construct should be sufficiently durable to last throughout the patient’s lifetime. This can be difficult to estimate and is based on multiple factors such as age, comorbidities, and extent of visceral and skeletal disease.

Even if the patient is expected to survive for > 3 months, the pain relief from stabilization of a fractured humerus, femur, or tibia is substantial. Even a nonambulatory patient might achieve enough pain relief and functional improvement if long bone fixation enables painless bed-to-chair transfers.

Asymptomatic lesions need only be followed clinically and radiographically. These lesions can be effectively managed with medical treatment including bisphosphonate therapy, treatment of underlying disease, and selective use of radiation. Surgery is indicated in a painful lesion in a weight-bearing bone that fails to respond to a trial of radiation therapy or is at a high-risk of fracture regardless of radiation. The clearest indication for surgical intervention is the presence of a pathological fracture in a weight-bearing long bone.

Preoperative Considerations
Preoperative planning must be thorough and extensive. The patient’s functional, medical, and nutritional levels must be established prior to any surgical intervention. Other medical problems are frequently encountered in the setting of metastatic disease, and conditions must be optimized in order to prevent or minimize complications. Close communication among the surgical team, the medical oncology team, and the anesthesia team is paramount.

Any sodium, potassium, or calcium abnormalities must be investigated and appropriately addressed. Attention must be paid to renal function and to hydration to prevent postoperative acute tubular necrosis. Liver function tests and coagulation markers will indicate the presence or absence of a coagulopathy. If the coagulopathy cannot be adequately corrected, surgery may be contraindicated.

Anemia often compounds extensive metastatic disease such that transfusions may be necessary preoperatively. One must also type and crossmatch the appropriate number of units ahead of time if extensive blood loss is expected intraoperatively. If no tourniquet
can be used, embolization can be considered preoperatively for vascular lesions such as those with renal and thyroid metastases.

Extensive chest disease might predispose the patient to intraoperative hypoxia, especially in the presence of embolization phenomena secondary to reaming long bones and pressurizing intramedullary canals with cement. When reaming or cementing an intramedullary canal, it is crucial that the surgeon notify the anesthesiologist in order to minimize hypotensive episodes and prevent an intraoperative cardiac event.15 If reaming or cementing is expected to be extensive, communication will enable the anesthesia team to plan ahead for more invasive hemodynamic monitoring and more aggressive hemodynamic support.

**Surgical Considerations**

The type and extent of surgery to be performed depend on many factors. As stated above, the first consideration is to be certain of the diagnosis because the treatment for metastatic disease differs from treatment for a primary bone sarcoma.

First, one must confirm that the lesion is metastatic and that there is indeed a histologic diagnosis.16 In a patient with a histologically proven primary carcinoma with extensive visceral and skeletal disease seen on staging scans, no biopsy is necessary. However, in the setting of the isolated bone lesion, a biopsy must be obtained. Biopsies may be performed percutaneously with image guidance or in an open manner in the operating room. In cases of an impending or a displaced pathological fracture, one may also proceed with an oncologically sound open biopsy of the lesion and perform an intraoperative frozen section. Close communication with the surgical pathologist is essential. If the diagnosis of metastatic carcinoma can be made on a frozen section intraoperatively, then the incision is lengthened and the lesion can be definitively addressed in the same operative setting. If there is any doubt about the pathological diagnosis, the wound should be closed and no further surgical intervention is warranted until the final diagnosis is established.

Second, depending on the amount of bone loss and soft-tissue infiltration as well as the natural history of the underlying tumor, the surgical options are internal fixation and endoprosthetic reconstruction/arthroplasty. In cases in which the tumor is growing rapidly and adjuvant radiation is relatively ineffective (as in renal cell carcinoma), the surgeon may consider a more aggressive surgical resection of the bone than would be necessary if more effective adjuvants were available. The goal in such cases is to minimize the risk and morbidity of a local recurrence. Most stabilization procedures with internal fixation utilize a long intramedullary nail/rod or a plate-and-screw construct. In this context, *nail* and *rod* are synonymous and imply an intramedullary tube of metal that load shares physiologic forces with the long bone. A plate-and-screw construct is extramedullary and is usually applied to the medial or lateral side of a long bone; hence it is considered a load-bearing construct. Any bone loss causing structural defects or deficiencies is best augmented with metal and bone cement. These areas can be curetted and scraped free of gross tumor and then backfilled with bone cement. There is rarely a role for a cadaveric bone graft in these scenarios: healing is prolonged and weight-bearing must be restricted. Moreover, the surgical field often undergoes postoperative radiation, further inhibiting osseous remodeling and incorporation of bone graft.

With periarticular lesions and with lesions causing extensive destruction and bone loss, consideration of resection and endoprosthetic arthroplasty is recommended. Rarely, when tumor involvement compromises soft tissues and infiltrates vital neurovascular structures, amputations are performed.18

Surgical intervention should ideally provide a reliable, predictable, and durable construct. It should span the entire long bone in case of disease progression and

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**Fig 1A-C.** — An 80-year-old woman with metastatic breast cancer. She had persistent left hip pain even after radiation therapy and was unable to walk secondary to pain. (A) X-rays showed a radiolucent lesion in her acetabulum. (B) A CT scan delineated the extent of destruction. (C) She underwent a total hip arthroplasty with a cage and cement reconstruction of her acetabulum.
should allow immediate stability for early mobilization and weight-bearing — hence the use of methylmethacrylate cement. Again, allograft incorporation into large bone defects takes months. Expecting patients with only months to live to stay off their limbs for the same amount of time is unreasonable. Furthermore, porous-coated implants that rely on bone ingrowth and ongrowth for stability do not function well in the face of pathological bone or bone that may soon become pathologic. Cement enables immediate filling of bony defects and confers immediate structural stability and support.

**Anatomic Criteria**

The surgical implant chosen must be tailored to the individual patient, the tumor biology, and its response to radiation, as well as to the anatomic location of the lesion. For example, Gainor and Buchert examined 129 pathological long bone fractures to determine the rate of osseous union. They found that the rate of fracture union varied depending on the type of tumor: 67% for multiple myeloma, 44% for renal carcinoma, and 37% for breast carcinoma. No fracture from lung carcinoma displayed complete healing, and none of those patients survived > 6 months. The authors also reported that a total radiation dose of 30 Gy or less did not prevent callus formation.

Below is a general discussion based on anatomic location. Though not all surgeons would agree with all of these options, this discussion provides an introductory framework for understanding surgical decision-making.

**Pelvis and Lower Extremity**

Lesions in the lower extremity involve weight-bearing bones. The surgical implants referred to below are utilized in the same location, whether the lesion is an impending or a displaced pathological fracture. When patients have a symptomatic, destructive lesion in the lower extremity, two options are available.

The first option is nonoperative treatment. Although avoiding surgery has obvious advantages, this path involves a prolonged, protracted course of protected weight-bearing that utilizes assistive devices such as crutches or a walker. Radiation is given concomitantly. If pain subsides, the patient may gradually progress to weight-bearing on the involved extremity, with the understanding that the bone may fracture at any time, without warning, throughout this process.

The second option involves surgical intervention. The anatomic location of the lesion and the extent of bone destruction often dictate the type of surgical instruments and implants required for stabilization and mobilization.

**Acetabulum:** Periacetabular lesions are usually treated with some form of hip arthroplasty, utilizing pins, cement, and multiholed cups and cages. An extensive periacetabular defect that cannot transmit lower-extremity forces to the spine requires a reconstruction of the pelvis. This can be accomplished with one of a variety of techniques, including a multiholed antiprotrusio cage, a Harrington pin and cement rebar reconstruction, or a custom-made metal prosthesis. The type of reconstruction used depends on the extent of bone loss. However, the unifying concept for all of these options is that they restore the pelvic anatomy sufficiently to allow transmission of the body weight from the extremity through the pelvis to the axial skeleton. The reconstruction is pursued if the implant is expected to last throughout the patient’s lifetime and if the patient can tolerate the postoperative recovery and rehabilitation processes (Fig 1).

**Femur:** The options for the femur depend on location and extent of disease. Lesions of the femoral neck and head are best treated with hip arthroplasty. These areas have an unacceptably high rate of failure when treated with internal fixation. If the acetabulum is free of disease, it can be left unresurfaced, and only

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**Fig 2A-B.** — A 69-year-old woman with a distant history of breast cancer. (A) She sustained a pathological right femoral neck fracture. CT scans showed no evidence of visceral disease, and a bone scan showed no evidence of lesions elsewhere. A needle biopsy confirmed metastatic carcinoma. (B) She underwent a cemented hemiarthroplasty.
a hemiarthroplasty is needed (Fig 2). The femoral stem must be cemented in this case; tumor-induced bone loss would prevent immediate stability with a press-fit cementless stem. Moreover, tumor progression can predispose a cementless prosthesis to early loosening, whereas full cement interdigitation can serve as a grout to protect against failure. The decision to perform a long-cemented stem in order to span the entire femur is controversial. If multifocal femoral disease is present, a long stem is required. In the absence of multifocal disease, the decision to use a long stem is based on surgeon preference. A long stem will protect the entire bone in case multifocal disease develops later. However, the risk of morbidity and mortality is higher, secondary to medullary embolization phenomena during cement pressurization and stem insertion. A short stem minimizes these risks but leaves the distal femur unprotected. Proponents of a short stem note that any disease that develops distally can be treated in isolation with internal fixation constructs.

Lesions of the femoral diaphysis are best treated with an intramedullary nail that spans the entire femur and must include fixation into the femoral neck and head. This is especially true for subtrochanteric lesions. This area just below the lesser trochanter transfers most of the weight-bearing forces. For this reason, even small lesions deserve extra attention and caution. The femoral neck and head and the distal femur must be sufficiently free of disease in order to provide adequate interlock fixation above and below the lesion. Proximal interlocking screws through the nail must pass through the femoral neck and head in order to protect this region from tumor spread and/or progression: hence the term cephalomedullary nail or rod (Figs 3 and 4). However, if the proximal femur bone quality is poor and if tumor involvement is extensive throughout the femoral neck and head, then an intramedullary nail will exhibit a higher rate of hardware failure secondary to loss of fixation and screw cut-out. In these instances, a calcar-replacing or megaprosthesis arthroplasty will provide a more stable and durable reconstruction.

Lesions in the distal femoral metaphysis and epiphysis are more amenable to curettage, cementation of defects, and internal fixation with a plate-and-screw construct. If bone loss is too extensive, then reconstruction via knee arthroplasty is the implant of choice. If standard knee arthroplasty instrumentation is inadequate, then a megaprosthesis in the form of a distal femur replacement is the next choice. Similarly, if the proximal femur is too extensively infiltrated to achieve nail or screw fixation, then endoprosthetic arthroplasty is indicated.

Tibia: Management of metastatic disease in the tibia has been well described. Lesions of the proximal tibial metaphysis and epiphysis are treated like those of the distal femur. Contained defects are best approached with curettage, cementation, and plate fixation. Lesions with diffuse bone loss and periarticular destruction require arthroplasty. Lesions of the tibial diaphysis are treated with an intramedullary nail provided there is enough proximal and distal bone for interlock fixation. Isolated defects in the distal tibial metaphysis and epiphysis can be considered for curettage, cement, and internal plate fixation. Rarely, if bone loss is diffuse and the soft-tissue infiltration is extensive, an amputation is performed.

Fig 3A-C. — A 69-year-old man with histologically established metastatic colorectal adenocarcinoma. (A) He had persistent left thigh pain associated with a lytic subtrochanteric lesion that failed to respond to radiation. CT scans and a bone scan showed extensive visceral and skeletal disease. (B-C) He underwent intramedullary nailing of the left femur.
Upper Extremity

It is easier for patients to restrict weight-bearing of the long bones of the upper extremity. For this reason, a trial of palliative radiation therapy and sling immobilization is reasonable as a first-line treatment for painful osseous lesions. However, if a patient requires the use of a cane or other ambulation or mobilization aid, prophylactic surgical stabilization is warranted and indicated. The type of implant depends on the anatomic location of the lesion.

Surgical options for the humerus depend on anatomy and extent of bone loss. A lesion destroying the humeral head and neck requires shoulder hemiarthroplasty. With loss of the proximal epiphysis and metaphysis, screw fixation with a nail or plate cannot be solidly achieved and will fail. A long stem should be cemented into the entire canal to protect the humerus from tumor spread and progression. If bone loss is severe and extends into the metaphyseal/diaphyseal junction, a proximal humerus megaprostheses will be necessary, and the prosthetic head is anchored to the remaining proximal soft tissues. This reconstruction is not designed for shoulder motion; rather, it serves to suspend the arm to allow a functional elbow, wrist, and hand. Patients should be counseled preoperatively regarding limited postoperative range of shoulder motion.

A lesion of the humeral diaphysis can be treated with an intramedullary nail or with plate fixation. The advantage of a nail is that it spans the entire humerus and can be inserted through a limited set of incisions (Fig 5). The disadvantage is that it violates the rotator cuff when inserted from proximal to distal. This can be a persistent source of postoperative shoulder pain in addition to prominent hardware irritation. The advantage of plate fixation is that it spares the rotator cuff. In addition, one can utilize the same incision for curettage and then fixation of the lesion. However, blood loss is greater because of the longer incision and larger dissection required. Moreover, the radial nerve, which powers wrist and digit extension, is at risk of injury as it loops around the humerus.

A lesion of the distal humeral metaphysis/diaphysis is best approached with plate fixation. The distal humerus flattens into the olecranon fossa and flares out with medial and lateral condyles; a nail would therefore not be suitable in this region. As with the femur and tibia, if the distal humerus has been destroyed, a megaprostheses is indicated.

Resection of the Isolated Bone Metastasis

The solitary osseous metastasis, particularly a renal cell metastasis, deserves special attention. Some reports suggest that wide en bloc resection of the isolated osseous renal cell lesion can improve survival. However, others have noted that, compared with stabilization alone, resection did not provide an advantage in overall survival. Apart from the specific surgical treatment, there may be a selection bias toward survival in patients with a solitary metastatic lesion.

Two reasons to argue for resection and reconstruction of the solitary lesion are for local tumor control and implant longevity. If these patients demonstrate superior survival outcomes, then resection with reconstruction may be a more durable and reliable long-term construct. However, prospective studies with long-term outcomes will be needed before this can be categorically affirmed.
Less Invasive Modalities

Less invasive modalities have been developed to address symptomatic osseous metastases as long as the structural integrity of the bone is not disturbed. These ablative techniques and technologies include radiofrequency ablation (RFA), cryoablation, focused ultrasound, and cementoplasty.35

RFA utilizes an electrode to cause thermal necrosis of the lesion. It has been used for osteoid osteomas and is applied here in the same way. Some authors have reported improved pain scores when utilizing this technique for patients with painful osseous metastases.36 RFA is not indicated for subcutaneous lesions, lesions in close proximity to neurovascular structures, or those that compromise stability in a weight-bearing bone.

Cryoablation is another interventional modality that causes lesion necrosis, this one by tissue freezing and then thawing. Argon gas is passed through an insulated cryoprobe. Gas expansion causes the temperature to drop substantially, freezing tissue surrounding the tip of the probe. With the use of multiple probes, multiple ice balls can be created and individually shaped to paint the lesion, under image guidance. Some studies have noted reduced pain scores when utilizing cryoablation under CT or MRI guidance.37

MRI-guided high-intensity focused ultrasound thermal ablation is a minimally invasive technique that can be used to provide palliation of pain from metastatic bone tumors. Ultrasound waves generated from a phased array transducer are passed through the body and focused at the site of disease. At the focus, the ultrasound energy converges and is converted to heat that results in tissue ablation of the target area while sparing the surrounding normal tissues. MR thermometry is used to monitor temperature changes and to guide the treatment process. This technique has been used with some success in providing pain relief to patients with metastatic bone disease who are not amenable to or have failed conventional treatments such as radiation and surgery.38

Cementoplasty is a technique in which polymethylmethacrylate cement is injected into a symptomatic osseous lesion. This method applies the principles used in kyphoplasty and vertebroplasty. A needle is injected into the osseous lesion under image guidance. Once needle placement is confirmed, cement is injected into the defect with the goals of pain relief and, possibly, mechanical stability. This has been described primarily for osteolytic defects of the pelvis, with reported success for pain and mobility at short-term follow-up.39 However, care and caution should be exercised since cement leakage around nerves and joints can cause neurologic and articular cartilage damage.

Conclusions

The surgical management of established osseous metastases must be individually tailored to each patient. Multidisciplinary support and communication with regard to a patient’s performance status and response to nonoperative therapies will assist the orthopedic sur-
geon in determining if surgical intervention is indicated and warranted. The surgical goals are pain relief and improved function. The surgical implant must not only allow immediate stability for mobilization and weight-bearing, but also provide a reliable, durable, and long-term construct that matches the expected long-term outcome of the patient.

References