Surgical Management of Metastatic Bone Disease

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Metastatic bone disease is a major contributor to the deterioration of the quality of life of patients with cancer; it causes pain, impending and actual pathological fractures, and loss of function and may also be associated with considerable metabolic alterations.

Operative treatment may be required for an impending or existing fracture and intractable pain. The goals of surgery are to provide local tumor control and allow immediate weight-bearing and function. Radiation therapy is often indicated postoperatively.

Detailed preoperative evaluation is required to assess the local extent of bone destruction and soft-tissue involvement, involvement of other skeletal sites, and the overall medical and oncological status.

After the lungs and liver, the skeleton is the most common site of metastatic disease. Prostate, breast, lung, kidney, and thyroid cancers account for 80% of all skeletal metastases. The femur, spine, humerus, pelvis, ribs, and skull are reported to be the most commonly affected sites, in that order. The prolonged survival of more patients with cancer has led to increasing numbers of individuals with metastatic bone disease. The exact incidence of bone metastasis is unknown, but it is estimated that 350,000 people die with bone metastases annually in the United States alone. Overall management of metastatic bone disease is estimated to result in as much as 17% of the total direct medical costs of cancer treatment in the United States.

Metastatic bone disease is a major contributor to the deterioration of the quality of life of patients with cancer. Impending and actual pathological fractures initiate the period of dependent care for many of them. The majority of metastatic bone lesions are treated effectively with nonsurgical modalities such as radiation therapy, chemotherapy, immunotherapy, hormonal therapy, bone-seeking isotopes, and bisphosphonates.

The use of chemotherapeutic and hormonal agents has improved the survival of patients with metastatic bone disease. Randomized trials comparing the newer class of aromatase inhibitors with a progesterational agent for postmenopausal women with metastatic breast cancer have shown better survival in the former group. The combination of chemotherapy with a monoclonal antibody to HER-2 (trastuzumab) or the combination of docetaxel and an oral 5-fluorouracil agent (capecitabine) has also been shown to improve the survival of patients who have metastatic breast cancer when compared with that of patients treated with standard chemotherapy alone.

Bisphosphonates reduce bone resorption by inhibiting osteoclast function, although direct and poorly understood antineoplastic effects may also occur. Administration of clodronate to patients who had breast cancer and were at high risk for distant metastases was shown to reduce the incidence and number of new osseous and visceral metastases. The addition of pamidronate to antineoplastic therapy for patients who had stage-IV breast cancer and osteolytic metastases resulted in a substantial reduction in the prevalence of skeletal complications (51% [186 of 367 patients] compared with 64% [246 of 384 patients not given pamidronate]) and a reduced rate of skeletal morbidity (2.4 compared with 3.7 events per year). Zoledronic acid normalized levels of N-telopeptide of type-I collagen.

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collagen within three months in 179 (81%) of 220 patients who had breast cancer with bone metastases, 135 (70%) of 193 patients with hormone-refractory prostate cancer, and seventy (80%) of eighty-seven patients with non-small-cell lung cancer. A normalized level of N-telopeptide of type-I collagen within three months after treatment, as compared with a persistently elevated level, was associated with reduced risks of skeletal complications (pathological fracture, the need for palliative radiation therapy or surgery to bone, and hypercalcemia of malignancy) and death. Zoledronic acid (4 mg infused over fifteen minutes) was also shown to reduce the rate of skeletal complications in patients with bone metastases from solid tumors other than breast and prostate cancer. However, bisphosphonates given intravenously at high doses or rapidly were shown to be associated with osteonecrosis of the jaw as well as with renal dysfunction. More recently, anti-angiogenic agents were also shown to be effective in the management of metastatic bone disease: SU11248, a multitargeted receptor tyrosine kinase inhibitor, demonstrated antitumor activity in metastatic renal cell carcinoma.

Treatment of pathological fractures with closed reduction and immobilization has been shown to be ineffective. Gainor and Buchert performed a study of 129 pathological fractures of long bones in 123 patients who had been treated with a variety of methods and followed until death or at least one year after the fracture. They observed fracture-healing in 87% (twenty-six) of thirty patients who were treated with internal fixation and radiation therapy and lived more than six months compared with 57% (thirteen) of twenty-three patients who had a similar survival time but were treated with cast immobilization and radiation therapy. As a result, those authors recommended the use of internal fixation and postoperative radiation.

Patients who have a slow-growing tumor that is responsive to chemotherapy and radiation therapy (such as multiple myeloma) and who have a pathological fracture of a non-weight-bearing bone may be initially treated nonoperatively. Operative treatment may be required for patients with an existing or impending pathological fracture or with intractable pain that does not respond to any nonoperative procedures.

Operative intervention for metastatic bone disease is usually a palliative procedure. The goals of surgery are to achieve local tumor control and structural stability of the surgically treated site and to restore function as quickly as possible. Ideally, operative treatment should allow immediate function and weight-bearing with the least possible morbidity and rehabilitation. Operative reconstruction in patients who have bone metastases must also be reliable and durable in accordance with the expected duration of survival, which may be prolonged for patients with breast, prostate, or renal cancer. Failure to achieve one of these goals usually necessitates a second operative intervention, leading to additional impairment of an already compromised quality of life. In their 1958 article, Bremner and Jelliffe stated that: “Most patients suffering long-bone pathological fracture have widespread disease, but it is wrong and unkind to regard this misfortune as a terminal event warranting only the simplest of symptomatic treatment. Recognition of this state of affairs demands the greatest expedition in returning the patient to comfort and mobility, that he may better enjoy his remaining months.”

This statement is even more relevant today because of the improved survival of patients who have metastatic bone disease and the newer techniques available for tumor resection and subsequent reconstruction of the defect.

The techniques for operative treatment of bone metastasis differ considerably from those used to fix a traumatic fracture because malignant tissue may need to be removed and because pathological fractures are associated with impaired bone-healing. The latter problem is attributed to extensive bone loss and destruction and to the postoperative radiation given to most patients. These unique features of the operative treatment of metastatic bone disease led to high rates of failure when standard fixation techniques were used. Yazawa et al. reported that 8.8% (thirteen) of 147 patients with a total of 166 metastatic lesions of the femur or humerus had a failure of operative treatment. The reasons for failure included poor initial fixation, improper implant selection, and progression of disease within the operative field. Similarly, Wedin et al. reported a failure of operative treatment, requiring a reoperation, of 11% (twenty-six) of 228 metastatic lesions in 192 patients.

The present review summarizes the principles by which patients who require operative treatment of metastatic bone disease are evaluated and managed. Adequate preoperative evaluation and adherence to surgical strategy may decrease the high rate of complications and reoperations in patients with metastatic bone disease.

**Indications**

Although planned operative treatment for patients with metastatic bone disease should not be delayed, establishing the diagnosis and preoperative evaluation and staging must not be rushed. This process, which must be thorough, should allow delineation of the osseous and soft-tissue extents of the lesion and their relationship to adjacent structures. It is also necessary to determine the overall skeletal involvement of the tumor, to detect any other metastases that may require concomitant operative treatment, and to evaluate the patient’s overall prognosis. Since the majority of patients who present with multiple skeletal metastases have an established diagnosis of cancer, clinical and radiographic evaluations are usually aimed at evaluating the extent of the disease and its complications rather than at identifying its site of origin. However, a systemic and detailed workup is required for patients who present with metastatic bone disease without an established diagnosis of cancer. Patients with a history of cancer who have a solitary bone lesion should not be assumed to have metastatic disease, or treated as if they do, unless a histological diagnosis has been obtained (Figure 1).

The medical history should include the current oncological status and related treatments and medications. In cases of spinal metastases, the medical history should focus on sensory and motor dysfunctions, walking ability, and urinary
and/or bowel incontinence. The physical examination should include an evaluation of the principal symptomatic area as well as other symptomatic sites. It should focus on the extent of soft-tissue tumor extension and its relationship to the neurovascular bundle of the extremity, the neurovascular status of the affected extremity, the presence of limb edema, muscle strength, and the range of motion of the adjacent joints. Assessment of the sphincter is mandatory for patients who have spinal metastases.

Laboratory studies should include complete hematologic and metabolic evaluations. Patients who have metastatic bone disease are often treated with chemotherapy and may have anemia and low platelet counts that must be addressed prior to an operation. Hypercalcemia most often develops in patients with squamous-cell lung cancer, breast cancer, kidney cancer, and certain hematologic cancers (particularly multiple myeloma and lymphoma). The signs and symptoms of hypercalcemia are nonspecific, and the clinician should have a high index of suspicion for this condition. Common symptoms include fatigue, anorexia, and constipation. If untreated, a progressive increase in the serum calcium level will likely result in deterioration of renal function and mental status. Death ultimately results from renal failure and cardiac arrhythmias.

Secretion of humoral and paracrine factors by tumor cells stimulates osteoclast activity and proliferation, and there is a marked increase in the markers of bone turnover. Numerous biochemical markers have been identified as correlating with bone turnover and resorption, although the value of these markers for monitoring the response to therapy or for the detection of bone metastases is still under investigation. Levels of bone-specific alkaline phosphatase, osteocalcin, and type-I procollagen C-propeptide in serum are indicators of osteoblast activity, whereas serum levels of C-terminal telopeptide of type-I collagen and tartrate-resistant acid phosphatase and urinary levels of type-I-collagen cross-linked N-telopeptides are markers of osteoclast activity.

When the diagnosis of metastatic bone disease is strongly considered, plain radiographs should be made of the affected site as well as of any other site at which the patient reports bone or joint pain. A computed tomography scan may also be required to detect metastases located in the shoulder girdle, spine, and pelvis because of the complex anatomy of these sites. Metastases located in long bones require biplanar radiographs because a single view may not provide enough information with which to evaluate the full extent of bone involvement (Figs. 2-A and 2-B). The combined results of these imaging studies will define the extent of bone destruction and soft-tissue extension. The latter may be relevant when the tumor is located in close proximity to a major neurovascular
bundle. Metastases located in long bones require plain radiographs of the entire extent of the bone in order to exclude the possibility of additional metastases for the purpose of surgical planning. Missed metastases proximal or distal to the level of fixation could cause pathological fractures on weight-bearing on the operatively treated extremity. Computed tomography scanning of the chest should also be routinely done as a screening study to rule out lung metastases or, alternatively, to determine whether the lung is the site of a heretofore unknown primary lesion.

A total-body bone scintigraphic evaluation with technetium-99m methylene diphosphonate is recommended prior to operative intervention. It allows detection of additional metastases that may require simultaneous surgical treatment. Bone scanning is highly sensitive for most bone lesions. Tracer uptake, however, is not specific for metastatic bone disease and may spuriously display a large variety of inflammatory, infectious, posttraumatic, and other benign conditions. Therefore, a plain radiograph should be made of any site that is found to be positive on the bone scan. It should be borne in mind that bone scanning is not a substitute for plain radiographs of the entire affected bone or other sites with bone pain because some tumors (such as renal cell carcinoma, multiple myeloma, metastatic melanoma, and thyroid carcinoma) may not be evident on a bone scan.

A sagittal, as well as axial and coronal, multilevel T1-weighted magnetic resonance imaging scan with gadolinium enhancement is a useful screening tool for patients who have spinal metastasis. It allows evaluation of the extent of medullary and extraspinal disease and spinal cord and nerve root compression. This information is essential when one is deciding whether to perform an operation or to treat the patient nonoperatively and, if the decision is to operate, which levels require decompression and fixation.

Operative treatment of metastatic bone disease cannot be carried out without an established histological diagnosis. When a patient has no previous histological diagnosis of metastatic bone disease, a biopsy is required to establish the diagnosis...
and exclude tumors that predictably respond to nonoperative treatment (e.g., lymphoma) or that require a different treatment strategy (e.g., sarcoma). Core-needle biopsies have been shown to have higher diagnostic accuracy than fine-needle aspirations for determining the type, grade, and specific diagnosis of musculoskeletal tumors\textsuperscript{45}. Examination of osseous material obtained after reaming a bone lesion may not contribute to an accurate diagnosis, and the results of such an evaluation should be interpreted with caution and an understanding of its limited value.

The indications for operative treatment of long-bone and pelvic girdle metastases include impending and pathological fractures and intractable pain\textsuperscript{37-39,44}. Patients with certain types of cancer who had a solitary bone metastasis were shown to have better survival than patients with similar types of cancer and multiple bone metastases\textsuperscript{40-47}. However, resection of such lesions was not shown to improve the outcome\textsuperscript{48}. Operative treatment of spinal metastases is indicated for patients with spinal instability or spinal cord compression\textsuperscript{49-53}. Patients with a very short life expectancy would not benefit from an operation because of the rapid general deterioration of their functional and physiological status and because of their inability to execute a minimal rehabilitation protocol. Considerations regarding the expected survival, the overall medical status and quality of life, and the magnitude of the operation and rehabilitation potential all contribute to the decision-making process\textsuperscript{54,55}. It is difficult and impractical to set a rigid time frame, but six to twelve weeks of expected survival is generally the minimum required for relatively simple procedures such as intramedullary nailing, and a minimum of six months is necessary for more complex procedures such as acetabular or endoprosthetic reconstruction.

The mere presence of lung metastases is not a contraindication to operative intervention since certain groups of patients with lung metastases have a relatively prolonged survival with reasonable respiratory function\textsuperscript{56}. In a prospective study of 460 patients in whom a fracture or an impending fracture of the acetabulum or a long bone had been treated operatively, as documented in the skeletal metastasis registry of the Scandinavian Sarcoma Group, several clinical variables were recognized as being prognostically important in identifying patients who are at high risk of dying in the first few months after an operation\textsuperscript{49}. Pathological fracture, visceral metastases, a hemoglobin level of <7 mmol/L, and lung cancer were independent negative prognostic factors for one-year survival, whereas myeloma was found to be the only positive prognostic factor\textsuperscript{57}. Similar results were reported by Nathan et al., who studied 191 patients who had undergone surgery for metastatic bone disease; they found that the Eastern Cooperative Oncology Group performance status, number of bone metastases, presence of visceral metastases, and hemoglobin level were independent predictors of survival\textsuperscript{58}. It is, therefore, advisable to collaborate with the responsible medical oncologist throughout the decision-making process to evaluate the patient's oncological status and life expectancy and to coordinate the planned operation with any other treatments planned for that patient.

**Impending Pathological Fractures and Spinal Instability**

Pathological fracture of a long weight-bearing bone has always been a consistent and clear indication for operative intervention. Identifying an impending fracture (i.e., identifying a metastatic lesion of a bone that is at risk of fracture) and recommending its prophylactic fixation in a patient with metastatic bone disease is an important issue. Elective fixation prevents the intense pain and the loss of function associated with a pathological fracture, and it is easier to perform than fixation of an existing pathological fracture. In addition, Ward et al. documented that patients who had prophylactic fixation of an impending fracture had a shorter hospital stay (mean, 5.6 compared with 7.8 days) and a higher likelihood of being discharged home rather than to a nursing home or rehabilitation facility (77% compared with 36%) as compared with patients who were treated surgically for an existing pathological fracture\textsuperscript{59}. It should be noted that that study was nonrandomized and retrospective, the patients did not undergo open curettage of the metastatic lesion, and polymethylmethacrylate was not used for fixation.

A common conception is that lytic metastases are likely to cause a pathological fracture while the new bone that is laid down by blastic metastases actually may increase cortical strength and make the bone locally harder\textsuperscript{39}. Saad et al. retrospectively reviewed the cases of 3049 patients with bone metastases and found that those with breast cancer, who usually have lytic bone metastases, had a higher rate of pathological fractures (35%; 393 of 1130) than did patients who had prostate cancer (19%; 122 of 640), in whom metastatic lesions are more often blastic\textsuperscript{60}. Recent studies indicate that the risk of skeletal complications in both patients with breast cancer and those with prostate cancer is strongly related to the rate of bone resorption\textsuperscript{61,62}.

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**TABLE I Mirels’s Scoring System for Risk of Pathological Fracture**\textsuperscript{65}

<table>
<thead>
<tr>
<th>Score (points)</th>
<th>Site</th>
<th>Radiographic Appearance</th>
<th>Bone Width Involved</th>
<th>Pain</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Upper extremity</td>
<td>Blastic</td>
<td>&lt;1/3</td>
<td>Mild</td>
</tr>
<tr>
<td>2</td>
<td>Lower extremity</td>
<td>Mixed (blastic-lytic)</td>
<td>1/3-2/3</td>
<td>Moderate</td>
</tr>
<tr>
<td>3</td>
<td>Peritrochanteric</td>
<td>Lytic</td>
<td>&gt;2/3</td>
<td>Functional*</td>
</tr>
</tbody>
</table>

*Aggravated by function.
Because of anatomical considerations, the definition of an impending fracture differs among the three major anatomical sites (long bones, acetabulum, and vertebrae) at which operative intervention for metastatic bone disease is often performed.

Numerous reports in the English-language literature describe attempts to identify impending fractures in long bones. Harrington’s classic definition of an impending pathological fracture of a long bone includes cortical bone destruction of ≥50%, a lesion of ≥2.5 cm in the proximal part of the femur, a pathological avulsion fracture of the lesser trochanter, or persistence of stress pain despite radiation therapy.

An avulsion fracture of the lesser trochanter in the absence of known antecedent trauma may be the initial manifestation of unrecognized metastatic bone disease. Phillips et al. hypothesized that these fractures occur when metastatic involvement of the intertrochanteric region becomes so marked that the normal pull of the iliopsoas muscle results in avulsion. Bertin et al. described four patients in which this occurred; the fractures healed, but a pathological subtrochanteric fracture subsequently occurred in three of the patients.

Mirels’s scoring system is based on four parameters (site, radiographic appearance, size, and related pain) for predicting the risk of fracture and for recommending appropriate treatment (Tables I and II). Mirels’s system has the advantage of being relatively simple. It is based on clinical evaluation and plain radiographs and has been shown to be reproducible, valid, and more sensitive than clinical judgment across experience levels. It is important, however, to realize that some patients with an impending fracture may not experience pain. Fidler reported that nine of nineteen patients who underwent prophylactic fixation of an impending fracture had not experienced pain before the impending fracture had been diagnosed.

Because of the complex anatomy of the acetabulum and the vertebrae, a simple definition of impending or pathological fracture is neither possible nor useful for planning surgical reconstruction at those sites. Instead, the location and extent of cortical destruction are used to evaluate the biomechanical impact on function.

Although the pelvis is a very common site of bone metastases, operative treatment of lesions in this area has not attracted as much attention as that in long bones or vertebrae. Operations are rarely required for pathological fractures of the pelvis other than those involving the acetabulum. In his 1981 report on fifty-eight patients who had a pathological fracture or cortical destruction of the acetabulum because of metastatic disease, Harrington classified the fractures on the basis of specific biomechanical deficiencies in the periacetabular bone.

Class I indicates that the lateral cortices and superior and medial walls are structurally intact; Class II, that the medial wall is deficient; Class III, that the lateral cortices and superior wall are deficient (Fig. 3); and Class IV, that there is extensive acetabular involvement (of the lateral cortices and superior and medial walls). Destruction of the superior and medial walls is usually considered to constitute mechanical compromise, thus necessitating operative intervention.

The debate about prophylactic fixation for the prevention of pathological fractures of long bones can also be applied to spinal metastases. Spinal instability is presumed if there is transitional deformity, vertebral body collapse of >50%, tumor involvement of two of three columns, or involvement of the same column at two or more adjacent levels. Kostuik et al. attempted to define spinal stability using a two-column concept of spinal architecture. According to their concept, the anterior column consists of the entire vertebral body whereas the posterior column consists of the pedicles, laminae, and spinous process. The anterior column is further divided into anterior and posterior halves as well as right and left sides, which results in four quadrants of the vertebral body. The posterior column is divided into right and left sides, for a total of six vertebral segments. Kostuik et al. considered the spine to be stable when

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**TABLE II Mirels’s Scoring-Based Treatment Recommendations**

<table>
<thead>
<tr>
<th>Total Mirels Score (points)</th>
<th>Risk of Fracture</th>
<th>Recommended Treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td>≥9</td>
<td>Impending</td>
<td>Prophylactic fixation</td>
</tr>
<tr>
<td>8</td>
<td>Borderline</td>
<td>Consideration of fixation</td>
</tr>
<tr>
<td>≤7</td>
<td>Not impending</td>
<td>Nonoperative treatment</td>
</tr>
</tbody>
</table>

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Fig. 3
A plain radiograph showing a Class-III acetabular metastasis, according to the Harrington classification, which includes deficiency of the lateral cortices and the superior wall. A computed tomography scan is required to determine the exact extent of bone and cortical destruction.
no more than two segments were destroyed, and they considered it to be unstable when three or more segments were destroyed. More recently, Tomita et al. grouped spinal tumors into three anatomical categories: intracompartmental (confinement of the tumor to the osseous elements of the vertebra), extracompartmental (occurrence of cortical breakthrough and tumor extension into the surrounding tissues), and metastases at multiple levels. These parameters as well as the grade of the lesion, the presence of visceral metastases, and the extent of metastatic bone disease elsewhere in the skeleton allowed the determination of a prognostic score, a general treatment plan, and a specific surgical strategy.

Spinal cord compression is a devastating complication of metastatic bone disease; it is defined as a mass lesion caused by tumor extension into the epidural space or a pathological spine fracture with displacement of the cord. It may present as a surgical emergency, with a rapidly evolving neurological deficit, or more subtly, with slowly progressive neurological dysfunction and pain. The expected recovery of patients with neurological dysfunction is related to the acuity of the symptom onset. Patchell et al. performed a randomized, nonblinded multi-institutional study to evaluate the efficacy of operative treatment and radiation therapy compared with that of radiation therapy alone in patients with spinal metastasis and spinal cord compression. The patients included in their study had an epidural mass compressing the cord with at least one neurological sign or symptom (including pain), good performance status, and a life expectancy of three months or more. The primary end point in that study was the ability to walk, and secondary end points were urinary continence, muscle strength, functional status, the need for steroid and/or analgesic medications, and survival. After an interim analysis, the study was ended because the criterion of a predetermined early stopping rule was met: significantly more patients were able to walk after treatment in the surgery group (forty-two of fifty; 84%) than in the radiation-therapy group (twenty-nine of fifty-one; 57%) (odds ratio 6.2 [95% confidence interval, 2.0 to 19.8]; p = 0.001). When the analysis included only the thirty-two patients who had been unable to walk when they entered the study, it was found that significantly more patients in the surgery group than in the radiation group regained the ability to walk (ten of sixteen compared with three of sixteen; p = 0.01). Operative treatment also resulted in substantial differences in continence (156 compared with seventeen days), survival time (126 compared with 100 days), muscle strength, functional ability, and reduction in steroid and opioid use. The authors concluded that direct decompressive surgery and postoperative radiation therapy is superior to treatment with radiation therapy alone for patients who have spinal metastases and spinal cord compression.

Intractable Pain and Solitary Metastases
Operative intervention may be required for relief of intractable pain associated with bone metastasis that has caused extensive bone destruction and has responded poorly to chemotherapy, narcotics, and radiation therapy.

A controversial issue is the operative management of a solitary bone metastasis and whether its removal has an impact on the patient’s survival. Operative treatment may be considered for tumors that are slow-growing, that are associated with a
good two-year survival rate, and for which there is no dependable oncological treatment. Metastatic renal cell and thyroid carcinomas are probably the only solitary bone metastases for which resection has been shown to be beneficial in terms of patient survival.

Operative Technique
The aims of operative management of bone metastases, regardless of the anatomical site, are relief of pain and restoration of function by achieving local tumor control and immediate mechanical stability. Local tumor control is usually accomplished by postoperative radiation therapy, with or without prior operative removal of the tumor. Tumor removal requires adequate exposure and should include curettage, drilling with a high-speed burr, and occasionally resection of the affected bone segment. Tumor removal may be associated with increased blood loss, an increased risk of infection, and local tumor seeding. These risks should be considered when local tumor progression cannot be controlled by nonoperative means and operative treatment is planned. For example, it may not be necessary to remove metastatic tumors, such as multiple myeloma and breast cancer, that are responsive to radiation therapy. Structural stability is achieved by using orthopaedic implants, with or without cement, and usually not with allografts or allograft-prosthesis composites, which rely on bone-healing. Bone cement augments structural stability and enables the patient to withstand the stress of immediate motion and function.

Goetz et al. reported on a series of forty-three patients with painful osteolytic bone metastases that had not responded to previous chemotherapy or radiation therapy and were treated with image-guided, percutaneous radiofrequency ablation of the tumor site. Twenty-four (56%) of the forty-three lesions were located in the pelvic girdle. Following radiofrequency ablation, 95% (forty-one) of the forty-three patients reported a clinically relevant decrease in pain. Although it has the advantage of being a minimally invasive treatment option for patients with intractable pain, radiofrequency ablation does not provide mechanical reinforcement of the tumor cavity, and operative treatment should be considered when such stability is required.

Selective arterial embolization within twenty-four hours before the operation is recommended for patients who have a metastatic renal cell or thyroid carcinoma since surgical manipulation of these hypervascular tumors may cause extensive bleeding.

Long Bones
Operative treatment of long-bone metastases usually consists of closed nailing, but wide exposure, tumor removal, and fixation with cemented hardware may be required. Closed nailing is done in the case of an impending or actual pathological fracture with minimal bone destruction and fragment displacement.
Open exposure may be required in cases of pathological fracture with considerable bone destruction. The following approach, which is our preference, entails adequate exposure of the tumor site with use of a large cortical window and tumor removal with handheld curets and drilling with a high-speed burr. Reconstruction begins with the introduction of an intramedullary nail. After the proper positioning and length are verified, the nail is partially withdrawn and the entire tumor cavity is filled with polymethylmethacrylate. The nail is then pushed back into the medullary canal and fixed with interlocking screws (Figs. 4 and 5). Intramedullary fixation devices are preferable for pathological fractures because of their superior ability to withstand mechanical loads, because they support the entire length of the affected bone, and because normal bone-healing cannot be expected. For example, a traumatic intertrochanteric fracture would be treated appropriately with a compression hip screw and side-plate device, whereas a pathological fracture in the same anatomical site would be best treated with a cephalomedullary nail. The use of side-plates for fixation is appropriate for lesions located in the upper extremity (for example, the humeral diaphysis), which is not subjected to considerable weight-bearing, or in places where it is difficult to use an intramedullary device (for example, the proximal tibial metaphysis).

Cases of extreme cortical destruction in which the remaining cortices cannot support a fixation device, and particularly in which the adjacent joint is destroyed, should be treated with resection and reconstruction with a cemented tumor prosthesis (Figs. 6-A, 6-B, and 6-C).

Amputations are rarely required but should be considered for palliation in cases in which bone destruction and tumor extension into the surrounding soft tissues are too extensive to allow reconstruction following wide tumor resection and in cases of neurovascular compromise of the affected extremity.

Acetabulum and Spine

In accordance with the classification system that he developed, Harrington also developed specialized operative techniques to ensure adequate support and fixation of the acetabular component of a total hip prosthesis in its normal anatomical position and to allow transmission of weight-bearing forces into bone that is functionally capable of withstanding the load. According to Harrington, patients with a Class-I lesion have sufficient periacetabular bone for conventional fixation of the cemented acetabular component. More recently, trabecular metal acetabular components have been used for that purpose in patients treated preoperatively with therapeutic pelvic radiation. Because of loss of medial structural continuity, Class-II lesions require the use of a protrusio acetabuli cup. Class-III lesions, in which all three elements of the acetabular cavity are violated, require a complex reconstruction of the missing cavity with cemented Steinmann pins or cannulated screws as reinforcement bars to support the protrusion cage. Class-IV lesions require internal hemipelvectomy for tumor removal, which leaves major bone loss and pelvic discontinuity. So-called saddle prostheses have been used effectively for reconstruction in these Class-IV cases. These prostheses, which articulate with the posterior part of the ilium, were originally designed for reconstruction in patients with a large acetabular bone deficiency, with or without infection, following total hip arthroplasty. Harrington et al. performed total hip arthroplasty in all of their patients, and a similar surgical strategy was reported by others. It is possible, however, that some patients with a Class-I lesion who have sufficient bone stock over the acetabular roof do not require joint replacement and can be treated with intralesional curettage and internal fixation with cement (Figs. 7-A and 7-B).

Like bone metastases elsewhere, spinal metastases often respond favorably to nonoperative treatment modalities. Operative treatment of spinal metastases is usually indicated when a patient has spinal instability, a progressive neurological deficit, intractable pain that is unresponsive to nonoperative treatment, or a lesion that is not responsive to radiation therapy. Harrington devised a five-category classification scheme for the management of spinal metastases based on the extent of bone destruction and neurological compromise. He recommended nonoperative treatment for patients who had (1) no important neurological compromise, (2) bone involvement without collapse or instability, or (3) major sensory or motor neurological compromise without substantial bone involvement. Operative treatment was recommended for patients who had either (1) vertebral collapse with pain resulting from a mechanical cause, but with no important neurological compromise, or (2) vertebral collapse or instability combined with major neurological compromise. Recently, treatment...
options have been tailored according to the status of the tumor and the overall oncological stage. Tomita et al. developed a scoring system on the basis of a retrospective survival analysis of sixty-seven patients. This system includes three major parameters: (1) grade of malignancy, (2) presence and possibility of treatment of visceral metastases, and (3) presence and extent of bone metastases. A numerical value is assigned to each category to calculate a prognostic score of 2 to 10 points. A prognostic score of 2 or 3 points suggests survival for more than two years and a recommendation for aggressive treatment (i.e., wide excision and fixation), and a score of 8, 9, or 10 points is indicative of short-term survival and a recommendation for nonoperative and supportive care. Palliative decompressive surgery can also be considered for the latter group. This scoring system was shown to be reliable, with a strong correlation with survival, in a prospective study of sixty-one patients.

Tokuhashi et al. used a system that included six categories: general condition, number of extraspinal bone metastases, number of vertebral body metastases, metastasis to major internal organs, primary site of malignancy, and neurological compromise. A numerical value was assigned to each category, and a strong correlation was shown between predicted and actual survival. Enkaoua et al. retrospectively evaluated this scoring system in a study of seventy-one patients who had spinal metastasis and confirmed its reliability as a prognostic tool. They recommended, however, that patients who have metastasis of unknown origin should receive a lower score. Tokuhashi et al. subsequently revised their original system and reported that the correlation between the scores derived with that system and the actual patient survival was better than that with the previous version. Ulmar et al. compared the validity of the scoring systems of Tokuhashi et al. and Tomita et al. with regard to their ability to predict the prognosis of patients who have spinal metastases of renal cell carcinoma and found the former to be superior.

Historically, laminectomy has been the surgical option for treatment of spinal cord compression, but laminectomy by itself does not address the anterior pathological involvement and thus may not suffice for cord decompression. Moreover, removal of the posterior elements may worsen the existing instability and deformity caused by tumor-related destruction of the vertebral body. Indeed, studies performed in the early
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If mechanical stability has been achieved, full weight-bearing on the affected extremity and passive and active range-of-motion exercises of the adjacent joints should be performed as soon as possible as determined on the basis of the wound-healing and the patient’s ability. Early discharge from the hospital will generally enhance the patient’s morale and minimize the interruption of an ongoing oncological program of treatment.

Following wound-healing, patients are referred for adjuvant radiation therapy to decrease the likelihood of local tumor recurrence. This usually consists of 3000 to 3500 Gy of external beam radiation given in several fractions, usually beginning no earlier than two weeks after the operation. In one study, patients with metastatic bone disease who underwent an operation and were given postoperative radiation therapy had higher rates of normal functional status and required fewer subsequent orthopaedic procedures than those treated with an operation alone. However, the better survival in that group might have been due to a referral bias consisting of patients with a better prognosis and medical status being assigned to that group. Adjuvant chemotherapy and immunotherapy are given on the basis of the specific tumor type and the relevant treatment protocol.

Functional and Oncological Outcomes

The survival of patients with cancer is usually determined more by the metastatic load in other sites than it is by metastases in the skeleton. Local tumor control, pain relief, and function are, therefore, the most appropriate criteria for evaluating the efficacy of operations done for metastatic bone disease. Although operative treatment is often carried out for metastatic bone disease, there have been only a few reports on the functional and oncological outcomes, which have demonstrated the ability to walk or good-to-excellent function in >50% of the patients who have undergone surgery. Major resection of metastatic lesions with prosthetic reconstruction has been shown to be associated with tolerable morbidity and to be rewarding in terms of functional results and local tumor control.

The above studies vary considerably with regard to the outcome parameters used to evaluate success. Instruments used for this assessment have included the Musculoskeletal Tumor Society and the Toronto Extremity Salvage Score scales, which were designed to evaluate function following limb-sparing tumor resection. Also used were the Eastern Cooperative Oncology Group scale, designed to evaluate progression of disease and its impact on daily living abilities, as well as the Short Form-36 questionnaire for evaluating general health status. The most consistent result of operative intervention for metastatic bone disease is the alleviation of pain, which was described by Bremner and Jelliffe in 1958 to be the most striking benefit of operative treatment. Similar observations of postoperative pain relief have been consistently made by others. A reoperation because of either local tumor progression or failure of fixation has been reported in less than 10% of patients.
References


