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Percutaneous Ablation: Safe, Effective Treatment of Bone Tumors

Ablative techniques have rapidly evolved and have been proven effective for treatment of benign skeletal lesions and, more recently, for palliation of painful metastatic skeletal disease. Treatment of primary bone lesions is largely restricted to benign lesions, such as osteoid osteomas, as a single-modality treatment or as an adjunct to surgical resection.[1-4] The use of ablation techniques for treatment of metastatic disease has developed because of the often disabling pain cancer patients experience. This pain can persist despite use of conventional therapies, including external beam radiation and opioid analgesics.[5-8]

Skeletal Lesions

Benign Skeletal Lesions: Osteoid Osteoma

Treatment of benign skeletal lesions with percutaneous ablation methods is an attractive alternative to or replacement for surgical resection because of the high effectiveness and low morbidity associated with these techniques.

Osteoid osteomas are relatively common, accounting for approximately 10% of benign bone tumors.[9] Prior to 1997 they were treated by

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ABSTRACT

Percutaneous radiofrequency ablation (RFA) of osteoid osteomas has replaced surgical excision as the preferred method for treatment of these benign lesions, due to high effectiveness and low morbidity. Both RFA and cryoablation are safe and effective for palliation of pain due to metastatic disease in patients who have failed conventional therapies. These image-guided treatments can be performed precisely, allowing safe treatment of complex metastatic tumors. A single ablation treatment is effective in most patients, is well tolerated, and provides a long duration of pain relief.

surgical excision. Despite the typical small size of the lesion, the operative resection could be extensive but often incomplete.[3] With improved precise localization using CT, the nidus of the lesion can be effectively located and the lesion completely treated with percutaneous radiofrequency ablation (RFA).[1,2,10-12]

Rosenthal has reported a 91% success rate for RFA as the initial treatment (107 of 117 procedures) and 60% for recurrent lesions (6 of 10 procedures).[4] Rosenthal also reported no significant difference in the rate of recurrence when osteoid osteoma lesions were treated with either surgical excision or percutaneous ablation.[3] Because of the equal efficacy of surgery compared with RFA and in light of the relatively low morbidity and lower costs associated with the percutaneous method,[13] most centers now consider RFA to be the standard treatment for osteoid osteoma.

Malignant Skeletal Lesions: Painful Metastatic Disease

Skeletal metastases are a common problem for cancer patients. They can have complications including pain, fractures, and decreased mobility that often reduce performance status, affect a patient's quality of life, and lead to depression and anxiety.[14,15]

External beam radiation therapy (RT) is the current standard of care for cancer patients who present with localized bone pain. This treatment results in a reduction in pain for the majority of these patients; however, 20% to 30% do not experience pain relief, and few options exist for these patients.[16-21]

Pain relief from RT may be transient for more than 50% of patients at a median of 15 weeks after completion of RT therapy.[22] Unfortunately, patients who have recurrent pain at a previously irradiated metastatic site are often not eligible for further

RT secondary to limitations in normal tissue tolerance. Additionally, metastatic disease in this patient population is frequently refractory to standard chemotherapy or hormonal therapy. Surgery, which is usually reserved for impending fracture, is not always an option when patients have advanced disease and poor functional status. Radiopharmaceuticals, which have known benefit in patients with diffuse painful bony metastases, are not considered standard of care for patients with isolated, painful lesions.

Analgesics remain the only alternative treatment option for many patients with painful metastatic disease. But obtaining sufficient pain control often involves side effects, such as constipation, nausea, and sedation.

Percutaneous Radiofrequency Ablation

A recent feasibility clinical trial and a subsequent international multicenter clinical trial of the use of percutaneous RFA for treatment of painful metastatic lesions involving bone found that this procedure is safe and provides significant relief of pain.^[5,7,8] It is important to note that these patients had failed conventional treatments, including RT and chemotherapy. They reported durable significant decreases in worst pain in a 24-hour period and a high level of pain relief (Figure 1). A total of 59 of 62 patients (95%) experienced a decrease in pain that was considered clinically significant using a predefined validated end point (\geq two-point drop in worst pain in a 24-hour period).^[23] Significant adverse events following the procedure were noted in four patients (6.5%).

Selection of patients for this treatment requires that they have significant pain (\geq 4/10 worst pain in a 24-hour period) and that the painful

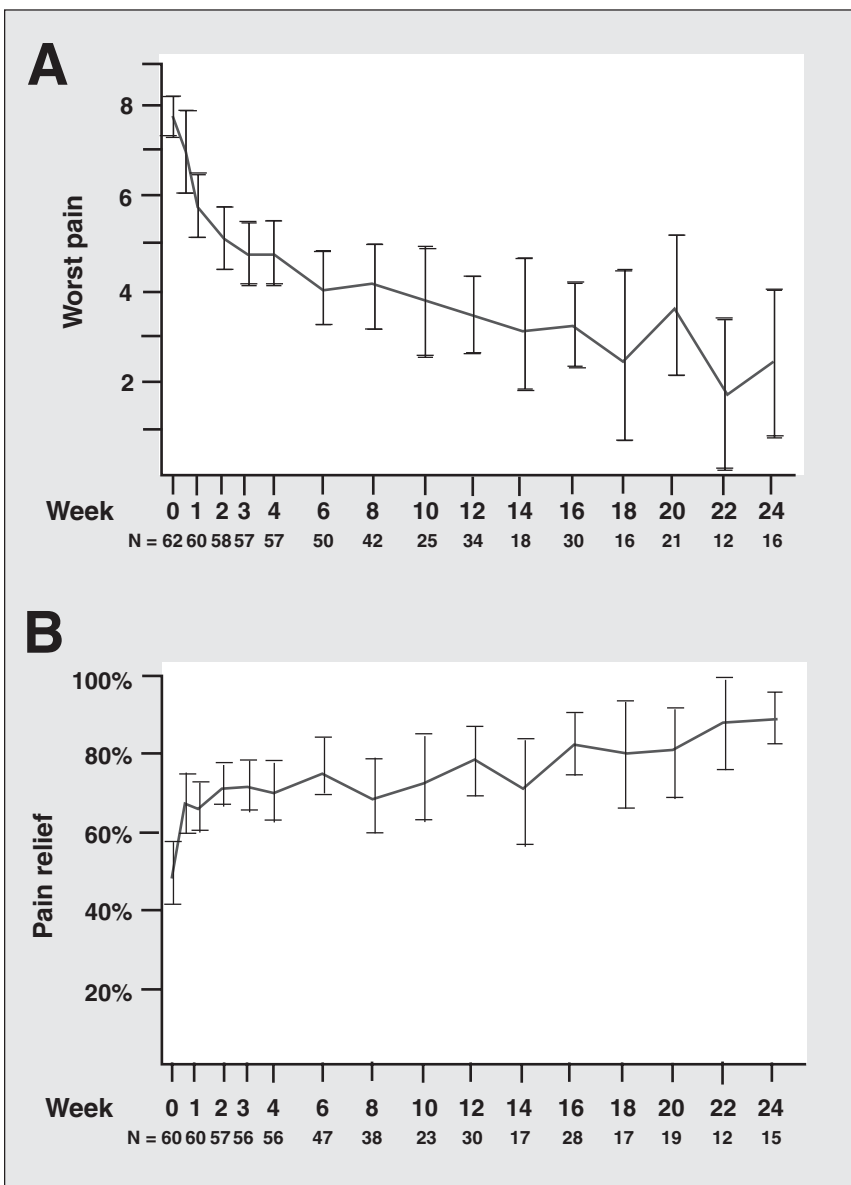


Figure 1: Mean BPI Pain Scores Over Time for Patients Treated With RFA— (A) Worst pain. (B) Pain relief from RFA and medications. Error bars represent 95% confidence intervals. BPI = Brief Pain Inventory; N = number of patients completing BPI form at each time point; RFA = radiofrequency ablation.

disease is limited to a few osteolytic metastases. The portions of metastatic tumors that are within 1 cm of critical structures—including bowel, bladder, spinal cord, or motor nerves—must be avoided to prevent damage to these structures. For example, a patient with metastatic melanoma had a painful metastasis involving the proximal tibia (Figure 2). Two separate deployments of the RF electrode were performed, treating both the osseous metastasis and

the metastasis overlying the tibia. Pain in the treated area was markedly improved over 3 to 4 weeks and completely eliminated after 6 weeks. Treatment response was durable over the 24-week follow-up period.

Percutaneous Cryoablation

Cryoablation has a long history of successful treatment of neoplasms in several organs, including prostate, kidney, liver, and the uterus. First-gener-

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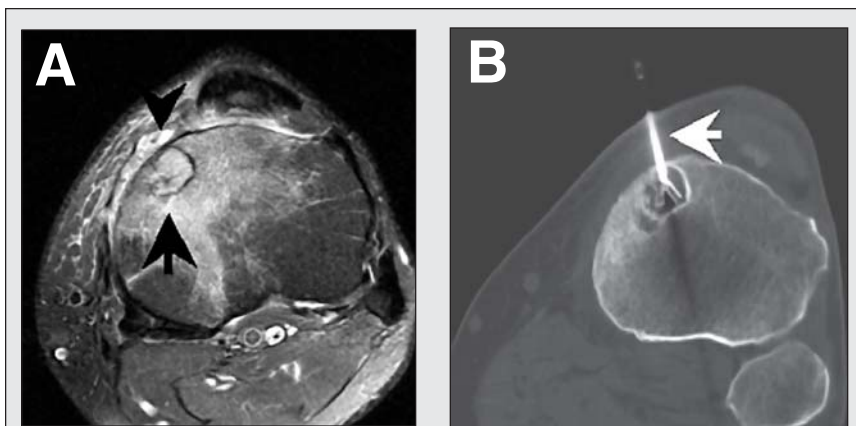


Figure 2: RF Electrode Placement—(A) Fat-suppressed T2-weighted axial magnetic resonance image of upper tibia and fibula. Metastatic malignant melanoma lesion contained within the tibia (arrow) with surrounding bony edema. Metastatic melanoma is also present in soft tissues overlying the anterior aspect of the tibia (arrowhead). (B) Axial CT image at corresponding level with RF electrode (arrow) placed within the osteolytic metastatic tumor. CT = computed tomography; RF = radiofrequency.

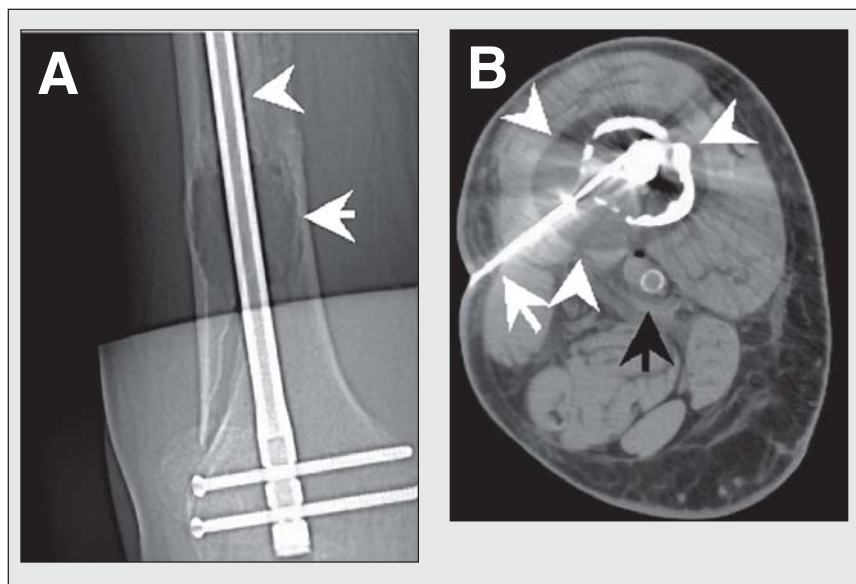


Figure 3: Right Femur, Percutaneous CT-Guided Placement of Three Cryoprobes—(A) Plain-film radiograph of right femur demonstrates an intramedullary rod (arrowhead) across an osteolytic destructive mid-diaphyseal metastasis (arrow) with a pathologic fracture. (B) Axial CT image shows that the iceball (white arrowheads) generated by the percutaneously placed probes (white arrow) encompasses the destructive lesion without involving adjacent vessels and nerves (black arrow). A small amount of gas adjacent to the femoral vein resulted from instillation of a small amount of saline in this region. The patient was unable to walk more than a short distance with the assistance of a cane prior to the procedure, with worst pain of 8/10. Twelve weeks following cryoablation treatment, he was able to walk without a cane, with worst pain of 3/10. CT = computed tomography.

ation devices were limited to intraoperative use because of their large diameter, the use of liquid nitrogen for tissue cooling, and the lack of well-insulated probes. Newly developed percutaneous cryoprobes are based on delivery of argon gas through a segmentally insulated probe, with rapid expansion of the gas resulting in rapid cooling, reaching -100°C within a few seconds. Active thawing of the iceball is achieved by actively instilling helium gas, instead of argon gas, into the cryoprobes.

As part of an ongoing prospective clinical trial, we have used cryoablation to treat 14 patients with painful metastatic disease involving bone. This effort involves patients who have one or two painful osteolytic lesions that cause $\geq 4/10$ pain in a 24-hour period. Patients' response to the treatment is assessed regularly over a 2-year period using the Brief Pain Inventory—Short Form (BPI), a validated visual analog scale for assessment of patient pain.

A 72-year-old man with metastatic renal cell carcinoma to the mid-shaft of the femur had 6/10 worst pain in a 24-hour period despite previous external beam radiation and intramedullary rod placement. He was treated by percutaneous computed tomography (CT)-guided placement of three cryoprobes (Figure 3). The iceball that was generated was monitored with intermittent CT imaging to both treat the target lesion and avoid the adjacent femoral artery and vein and the sciatic nerve. Pain from the metastatic lesion was markedly reduced following treatment and, most importantly, the patient reported an improved quality of life with resumption of an active lifestyle.

Preliminary analysis of the patients treated to date is encouraging. Prior to cryoablation, the mean score for worst pain in a 24-hour period was 6.7/10 with a range of 5/10 to 10/10. At 4 weeks after cryoablation, the mean score for worst pain in a 24-hour period decreased to 3.8/10 (standard deviation = 0.5, $P = .0003$). During the follow-up, 86% of the treated patients reported at least a three-point drop in their worst pain, with 50% reporting complete relief of

pain. All patients who were prescribed narcotics prior to the procedure reported a reduction in the use of narcotic analgesic medications at some time following cryoablation. No serious complications have been observed.

Some lesions at risk for fracture may also be treated with ablation followed by cementoplasty the next day. A 65-year-old man with lung cancer presented with left hip pain on walking. Upon CT examination an osteolytic supra-acetabular metastasis with preserved cortex at the level of the hip joint (Figure 4A) was found. Treatment considerations included resection and stabilization of the acetabulum because of fracture risk, radiation therapy, and percutaneous ablation followed by cementoplasty. The patient elected for the percutaneous approach and was treated with cryoablation and cementoplasty on the following day (Figures 4B and 4C). He reports no pain in the treated region, and no fracture or progression has occurred at the treated site after 18 months.

Both cryoablation and RFA are effective for palliation of pain due to metastatic disease in patients who have failed conventional therapies. The significant advantages of percutaneous cryoablation relative to RF ablation for treatment of painful metastases are as follows:

- The iceball, which defines the limits of the zone of ablation, can be readily identified with CT imaging.

- The simultaneous use of multiple cryoprobes allows generation of large zones of ablation (> 8-cm diameter).

- Simultaneous use of several cryoprobes eliminates possible residual disease that can result along the boundaries of overlapping sequential ablations.[24]

- The cryoablation procedure is compatible with the use of tissue displacement devices such as balloons that allow safe treatment of lesions adjacent to bowel.

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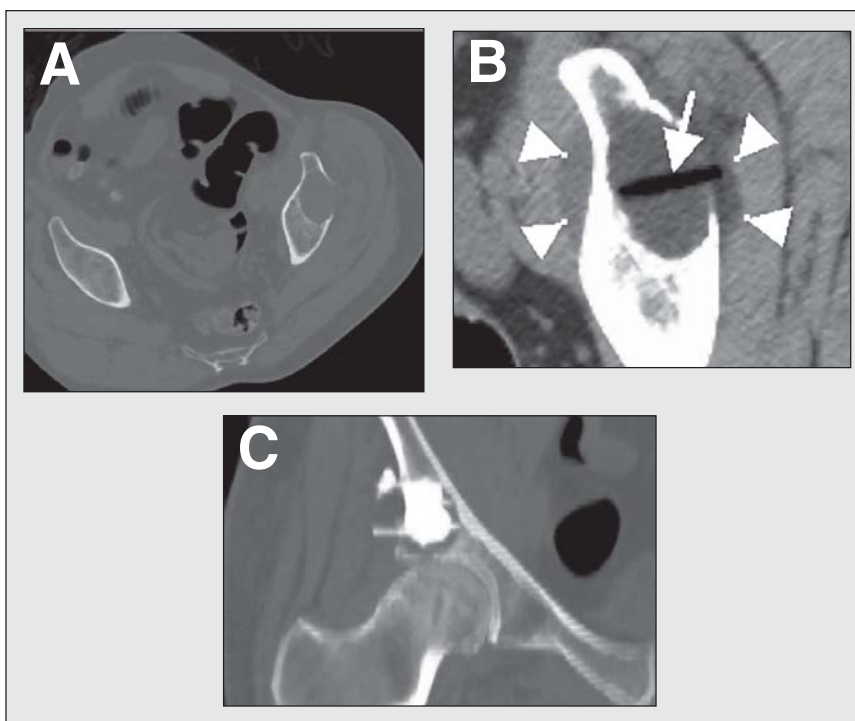


Figure 4: Formation of Iceball and Follow-up CT—(A) Noncontrast CT demonstrates osteolytic metastasis involving the right periacetabular region. (B) Noncontrast CT immediately following removal of the cryoprobe with probe tract (arrow) in the center of the low-attenuation iceball (arrowheads). Iceball completely encompasses the metastatic tumor. (C) Coronal noncontrast CT following cementoplasty. CT = computed tomography.

- In contrast to RFA, cryoablation has mild or no significant pain associated with the procedure or in the immediate posttreatment period. One drawback of the use of cryoablation is that the procedure requires, on average, 2 to 3 hours. This is approximately 1 hour longer than the time needed for RF ablation.

Conclusion

Percutaneous RFA of osteoid osteomas has replaced surgical excision as the preferred method for treatment of these benign lesions. Percutaneous ablation is also an important treatment method for managing pain due to bony metastatic disease. These image-guided treatments can be performed precisely, allowing safe treatment of complex metastatic tumors. A single ablation treatment is effective in most patients, is well tolerated, and provides a long duration of pain relief.

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