Vertebral Augmentation and Ablation in Cancer Patients With Spine Metastases

Insights into the pivotal role these methods play in the multidisciplinary management of spinal metastases and the differences between treatment for pathologic compression and osteoporotic fractures.

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Bone metastases are the third most common site of metastatic disease in patients with cancer, with the spine as the most common site of bone metastasis.[1-3] Up to 40% of patients with cancer will develop spine metastases, with a reported incidence of approximately 120,000 new cases each year. For some malignancies such as breast or prostate cancer, spine metastases may occur in as many as 70% to 90% of patients. The development of spine metastases is a powerful prognostic indicator because the overall median survival after diagnosis is 7 months and can be as low as 3 months for patients with epidural extension. As systemic cancer treatments advance and the diagnosis of cancer progresses to a chronic disease state, there is an increasing need for focal treatments to provide both a palliative pain measure and a local control effect for spine metastases.

The most common presenting symptom for patients with spine metastases is pain.[4] Pain is the consequence of two principal generators: mechanical instability and biologic factors. Mechanical pain arises from the weakening of the structural integrity of the spinal column due to bony erosion and/or disorganized bony remodeling. Biologic factors that contribute to pain include the periosteal inflammatory response to the presence of tumor in the bone. Moreover, direct tumor invasion of perineural tissue as well as compression of the cord or exiting nerve roots can manifest as pain. Tumors can also directly elaborate inflammatory cytokines that can result in focal bone pain.

The treatment of spinal metastases centers on therapies that directly address both of these orthogonal axes. That is, current approaches are designed to address both the tumor itself as well as the mechanical instability. Due to recent advances in minimally invasive spine stabilization devices and ablation modalities, the image-guided interventionalist's contemporary tool kit is well suited to contribute to the care of patients with spinal metastases. This article provides a practical approach to vertebral augmentation and ablation in patients with cancer based on the literature and our clinical experience. Our goals are to highlight how treatment approaches for pathologic compression fractures differ from those of osteoporotic fractures as well as the pivotal role that vertebral augmentation and ablation have in the multidisciplinary management of cancer patients with spine metastases.

PATIENT SELECTION: A MULTIDISCIPLINARY APPROACH

Vertebral augmentation and spine ablation are important components of the overall treatment portfolio for spine metastases. The decision to perform these procedures is best made in a multidisciplinary setting in collaboration with the relevant specialties, including medical oncology, neurosurgery or orthopedic surgery, and radiation oncology. This collaboration is particularly important given advancements in percutaneous techniques and recent paradigm shifts in radiation therapy and surgical approaches. The historic methods of en bloc surgical resection and palliative conventional external beam radiotherapy (EBRT) have evolved to include less invasive separation surgery and the radiation therapy approach of spine stereotactic body radiotherapy/stereotactic spine radiosurgery (SSRS). The latter in particular has had a profound impact on the management of spine metastases, resulting in improved tumor control and more durable symptom relief compared with conventional EBRT.[5,6]

The most common indication for intervention in patients with spine metastases is pain palliation. Although radiation therapy is often the cornerstone in the management of this disease, there are several reasons why vertebral augmentation and spine ablation can play a complementary role. Most importantly, radiation is well suited to address the biologic factors causing pain but does not address mechanical pain generators. Additionally, pain relief from radiation therapy may take several weeks to manifest, and the pain may worsen before it improves. This flare phenomenon is well described and is particularly true for hypofractionated, stereotactic radiation modalities. On the other hand, the pain relief with ablation and vertebral augmentation is often much more rapid. Stereotactic radiation modalities are also associated with a greater risk of postradiation fractures compared with conventional EBRT, a complication that can develop in 11% to 39% of patients.[7] For these patients, postradiation stabilization should be considered, particularly for vertebral bodies with anterior column disruption. Importantly, we have not observed any instances of delayed wound healing or other negative ramifications of combining vertebral augmentation/spine ablation with SSRS, even when the two interventions were performed within 24 hours. Furthermore, patients with severe pain from unstable compression fractures may not be able to lay still for the 30- to 45-minute radiation simulation sessions; therefore, the stabilizing palliative effect of vertebral augmentation is often beneficial before radiation therapy is initiated.

The patient's overall oncologic history and active treatment plan should also be considered prior to any spine intervention. Both vertebral augmentation and spine ablation can be safely combined with systemic chemotherapies. It is typically advised to time these procedures to avoid nadirs in coagulation parameters for patients on myelosuppressive therapies. Typical clinical parameters for percutaneous vertebroplasty recommend that platelet counts exceed 50,000/µL. Molecularly targeted therapies such as the use of tyrosine kinase inhibitors may be held for 1 to 2 days before and after the procedure. For patients on systemic immunotherapies such as checkpoint inhibitors, there is typically plenty of time between each cycle (generally scheduled every 2-4 weeks) to perform the procedure.

SPINE ABLATION

Several ablation modalities have been applied toward the treatment of spine metastases, including radiofrequency (RF) ablation, cryoablation, laser ablation, and microwave ablation. The latter three may have niche roles, but RF ablation is the mainstay in our practice. This preference is based on both the well-established safety profile and the preponderance of clinical data supporting the effectiveness of RF ablation in cancer bone pain relief. Indeed, the data behind the use of RF ablation for painful bone metastases are among the highest quality available across the gamut of interventional oncology procedures, and they include several multicenter prospective clinical trials.[8,9] As a reflection of the strength of these data, RF ablation is acknowledged as a treatment consideration for patients with local bone pain by the National Comprehensive Cancer Network adult cancer pain guidelines.[10]

Given the high-quality data supporting the use of this modality, it is our practice to perform RF ablation whenever we treat pathologic compression fractures. Our preference is to use RF ablation systems specifically designed for spine ablation (eg, OsteoCool, Medtronic; Star, Merit Medical Systems, Inc.). Both of these systems have feedback mechanisms and provide real-time thermal data to minimize the risk of nerve or spinal cord injury. Because ablation zones within bone are difficult to visualize on conventional intraprocedural imaging regardless of ablation modality, the superior safety profile of these dedicated RF spine ablation systems provides the operator with confidence to thoroughly treat vertebral body metastases while minimizing nerve damage risks. Although these spine-dedicated RF systems are preferred for the vertebral body, cryoablation can be particularly helpful for the treatment of lytic lesions involving the posterior elements or the costovertebral junction. In these locations, the visibility of the cryoablation ice ball in the surrounding soft tissues on cross-sectional imaging can be very beneficial.

Ablation planning is approached similarly, whether the therapy is applied through percutaneous ablation or radiation therapy. Both specialties aim to cover as much of the metastasis as safely possible, often with extension into the surrounding vertebral body for a more comprehensive treatment effect (Figure 1). Even if the tumor is small and focal, pain can be generated by periosteal inflammation and other biologic factors that are not confined to the tumor. For percutaneous ablation, the approach typically involves bilateral (usually transpedicular) access to ensure adequate ablation impact.

Once the ablation probes are in position, three optional methods to monitor for nerve ablation can be implemented for an extra degree of reassurance: (1) thermocouples can be strategically positioned between the ablation zone and the spinal cord or foraminal nerve root; (2) neurologic monitoring (electromyography, evoked potentials, etc) can be arranged; and (3) physiologic monitoring for symptoms can be assessed with the patient awake during spine ablation so he or she can provide feedback. Although each of these methods does confer added safety benefit, the advancement of spine-specific ablation devices has largely obviated the need for such additional measures in the absence of effacement of the posterior vertebral body wall and epidural extension. Rarely, ablation may be performed for patients with epidural disease; this scenario may arise in those who have already received radiation and are not surgical candidates. Ablation targeting the posterior third of the vertebral body can lead to tissue retraction and reduction in tumor extension into the anterior epidural space. These procedures are best performed with one or multiple forms of neurologic monitoring due to the increased risk for irreparable nerve damage.

Stabilization of the vertebral body after ablation is important because most spine ablation procedures are performed in the palliative setting to address tumor-related pain and instability from osseous erosion. In addition, ablation is known to increase fracture risk, and dedicated spine RF systems have been designed to make the two-step process of ablation augmentation as seamless as possible. It is important to note that a spine metastasis does not need to cause a fracture to cause pain. Spine ablation can provide pain relief in these settings, but we follow ablation with vertebral augmentation to prophylactically reduce the risk of subsequent fracture.

VERTEBRAL AUGMENTATION

Vertebral augmentation is the least invasive technique to address pain caused by mechanical instability from a pathologic compression fracture. This practice is well supported by evidence in the literature.[11]

It is prudent to highlight some differences in vertebral augmentation when applied for osteoporotic versus pathologic compression fractures. Patients with cancer are likely to be on a form of systemic anticancer therapy and may have multiorgan metastatic disease that can impact overall health or result in bleeding dyscrasias. The goals of care and life expectancy are also likely to be substantially different. From a procedural standpoint, the cement distribution during augmentation procedures can be unpredictable due to various tumor factors, and cement delivery requires vigilant monitoring with imaging equipment throughout the injection. Factors affecting cement dispersal include increased tumor vascularity leading to early intravasation, imperceptible fracture planes in irregular and oblique orientations, a greater concern for leakage into the spinal canal due to erosion of the posterior cortical wall, heterogeneous composition of the metastasis-bearing bone (lytic, sclerotic, or both), and the presence of tumor extension into the anterior epidural space. Each of these additional variables can be addressed by thoughtful planning and execution. Although important for the workup of osteoporotic fractures, MRI is equally if not more important for pathologic fractures. In addition to characterizing fracture acuity, MRI is also indispensable in defining tumor vascularity, active versus treated lesions, tumor margins within the bone, and the presence of epidural spread. Lastly, MRI can also highlight occult lesions in adjacent levels that may be causing pain and should be considered for treatment as well.

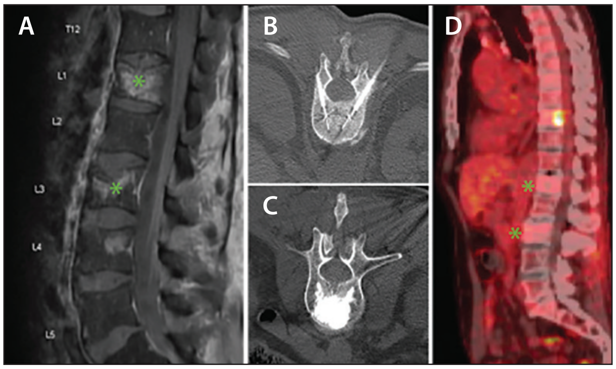

Figure 1. A patient with a metastatic neuroendocrine tumor was noted on MRI to have multiple spinal metastases, including symptomatic pathologic compression fractures of L1 and L3 (asterisks; A). These levels were treated with RF ablation and kyphoplasty (B, C). A follow-up fluorodeoxyglucose positron emission tomography scan 1 month after the procedure demonstrated no residual metabolic activity at the treated levels (asterisks; D), indicating successful local control at those sites of disease.

Sclerotic spine metastases, such as those in patients with breast or prostate cancer, can pose several unique challenges to both cement augmentation and spinal ablation (Figure 2). In fact, it may seem somewhat counterintuitive to treat lesions that appear dense on CT or radiographs; however, these lesions can undermine the structural integrity of the vertebral body. An imag-

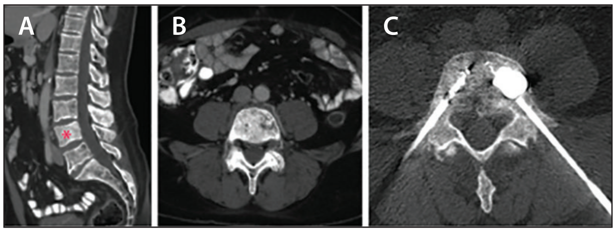

Figure 2. A patient with metastatic prostate cancer was noted to have a sclerotic, painful lesion occupying the majority of the L4 vertebral body (asterisk) (A, B). This lesion was treated with RF ablation followed by kyphoplasty (C). Note the inability of the kyphoplasty balloon to inflate in the area of dense sclerosis involving the right half of the vertebral body.

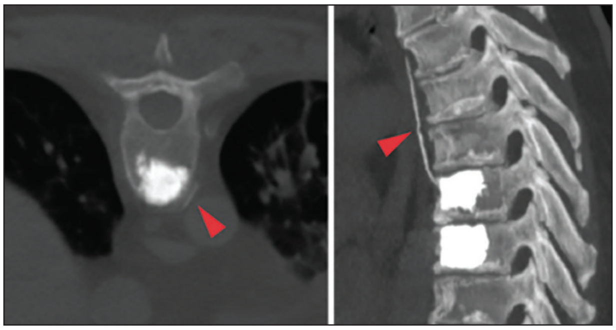

Figure 3. A patient with renal cell carcinoma with thoracic spine metastases was treated with RF ablation and kyphoplasty. Cement intravasation was noted during the procedure into the azygos vein (arrowheads).

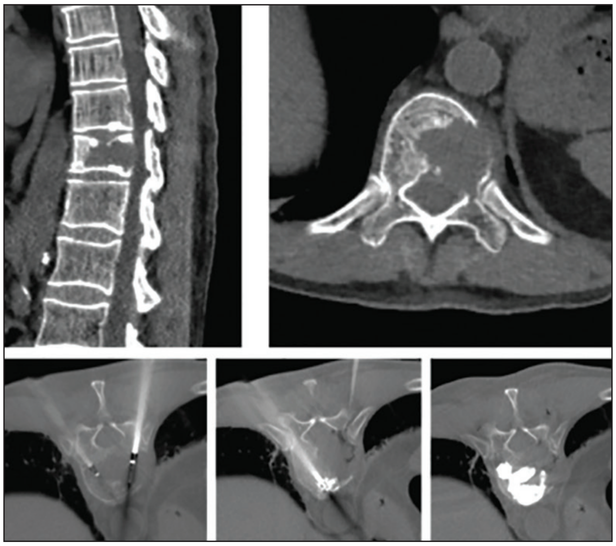

Figure 4. A patient with metastatic renal cell carcinoma to the spine resulting in posterior wall disruption was treated with RF ablation and kyphoplasty. With careful technique, a sufficient quantity of cement can be delivered into the vertebral body to provide stabilization without leakage into the spinal canal.

ing finding of rapidly expanding sclerotic fracture, with evidence for pathologic compression fracture or focal edema on MRI and in association with focal pain, should prompt evaluation for treatment. The first challenge in the treatment of sclerotic metastases is often the first step: advancing the access needles into the vertebral body. Hand-held, battery-powered bone drills may be helpful to bore access and prevent damage to needles during vigorous application of a mallet. When access to the sclerotic lesion is achieved, the intrinsic dehydrated state of these lesion increases impedance, which will result in a smaller than expected RF ablation zone. This can be mitigated by performing multiple overlapping ablation zones, with time between ablations to allow for rehydration of the tissue. On completion of ablation, the final challenge is controlled cement distribution, a challenge that is compounded by the fact that adjuvant maneuvers such as balloon kyphoplasty and spine implants are irrelevant because balloons will not inflate and implantable devices might not deploy as expected in sclerotic lesions. If possible, the best practice in this scenario is to advance the vertebral access needles across both the sclerotic lesion and nontumorous osseous matrix to improve distribution. Bilateral access is often beneficial, and CT guidance can be invaluable for confirming needle position prior to cement delivery.

The most common risk with vertebral augmentation in pathologic compression fractures is cement leakage. The incidence of leakage has been reported to be as high as 70% in these procedures.[12] Leakage can occur in two forms: intravascular (ie, intravasation) or extravascular. Based on our experience, the latter is most common when treating lesions in the upper thoracic spine due to short venous connections that feed directly into the azygos vein (Figure 3). The most concerning form of extravascular leakage is when cement extends posteriorly into the epidural space, resulting in the spinal canal narrowing. Approximately 70% of patients in our practice have some degree of posterior wall cortical disruption and thus are potentially at risk for this complication (Figure 4). Cement can also leak along the margins of the vertebral body and into the neuroforamina, and although the cement may not directly cause nerve compression, the exothermic reaction from the cement curing process can lead to thermal injury to the exiting nerve root. For patients at an increased predisposition for leakage, we prefer to use viscous cement and slowly deliver the cement under vigilant monitoring with frequent fluoroscopic or CT guidance. Again, bilateral

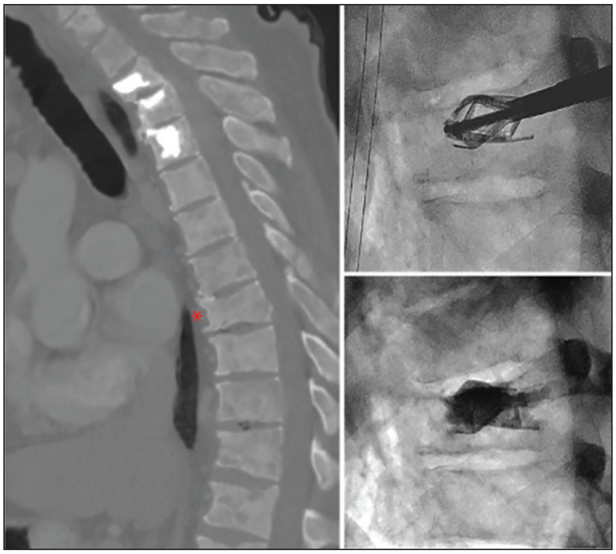

Figure 5. A patient with metastatic breast cancer and a pathologic fracture of the thoracic spine (asterisk) was treated with kyphoplasty using the SpineJack device (Stryker). This device can function as a scaffold to allow adequate cement augmentation.

access can prove helpful in providing an alternative delivery route if the initial access leads to cement leakage. Although not in real-time like fluoroscopic guidance, cement delivery under CT guidance can prove helpful if greater spatial detail is required for high-risk procedures in which cement leakage is anticipated into the spinal canal or neuroforamen.

Balloon kyphoplasty and spine-implantable devices can also be very helpful for controlling cement distribution within pathologic fractures. As opposed to their use in osteoporotic fractures, these devices are useful not only for their ability to restore vertebral body height but also to serve as a scaffold for cement deposition (Figure 5). Indeed, it is important to recognize that in vertebral bodies with extensive lytic bone destruction, there is little residual bone for the implantable device to anchor into, and so the devices tend to migrate. In these settings, there is no substitute for the comprehensive cementing of the entire vertebral body.

CONCLUSION

The management of spinal metastases is a rapidly evolving field with recent practice-changing advances in surgical, radiation oncologic, and image-guided approaches. As is true across the spectrum of interventional oncology, a multidisciplinary approach is essential to ensure optimal care. Rooted in high-quality data, spine ablation and vertebral augmentation are indispensable components of the contemporary treatment algorithm. With careful attention to technical approaches that differ from the management of osteoporotic fractures, interventional oncologists can provide profound improvements in patient outcomes with these interventions. ■

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