Global Approach to the Patient with Pain in Interventional Radiology

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The number of palliative procedures available to the interventional radiologist has rapidly expanded during recent years, and the need for continued implementation and innovation in this space is at an all-time high. The overuse of opioid analgesics has created a serious public health crisis, and the United States Centers for Disease Control and Prevention has called upon physicians to develop nonpharmacologic therapies for pain, stating clearly that procedures with adequate evidence of safety and efficacy are preferable to opioids for the management of chronic pain.¹ As interventional radiologists, we are uniquely equipped to deliver existing solutions and develop new alternatives through the application of advanced imaging guidance. Moreover, multiple percutaneous techniques have independently evolved in recent years for the management of cancer-related pain.^{2–4}

The approach to a patient with pain who presents to interventional radiology can be simplified through the following algorithm (►Fig. 1). Four categories of advanced interventional pain management techniques can be defined such that the options for therapy can be grouped to spine pain related to cancer, nonspine pain related to cancer, spine pain that is unrelated to cancer, and nonspine pain that is unrelated to cancer.

Spine Pain Related to Cancer

The patient with metastatic disease to the vertebral column will experience pain as a result of neoplastic contact with bones and adjacent soft tissues and/or pathologic fracture of a vertebral body. The most common of these presentations is metastatic disease leading to vertebral body fracture, a scenario for which percutaneous coaxial radiofrequency ablation (RFA) and cementoplasty has recently been shown to be safe and efficacious.^{5–10}

Our approach to a metastatic lesion involving the spine is outlined in ►Fig. 2. Workup begins with examination of the patient and determination of whether the chief complaint is referable to the lesion. The presence of a lesion on imaging may or may not translate to clinical symptoms, and correlation with location and severity of the patient's pain with imaging findings is a critical first step.

The second step in evaluating a patient presenting with pain associated with a metastatic spinal lesion is the search for an associated fracture. Pain relief following percutaneous RFA and cementoplasty is largely related to stabilization of fracture fragments. If no fracture is present, we consider alternative image-guided ablative techniques, such as cryoablation.

If initial evaluation of the patient and recent imaging reveals a neoplastic lesion that is clearly causing pain and is associated with a fractured vertebral body, the next step in our algorithm is to determine whether the lesion is sclerotic or lytic. Sclerotic lesions can be difficult to access percutaneously for radiofrequency and cementoplasty treatment, and as such may be better treated with alternative modalities such as radiation.

Finally, interrogation of the images for epidural involvement by neoplasm is an important element when considering percutaneous treatment. The degree and location of epidural involvement (above or below the cauda equina) must be weighed as risk against potential palliation of symptoms in the context of previous therapies, overall prognosis, and available alternative therapies.

There are two available RFA devices suitable for spinal use: OsteoCool RF Ablation System by Medtronic (Minneapolis, MN) and STAR Tumor Ablation System by Merit Medical Systems (South Jordan, UT). The OsteoCool RF Ablation Probe is a rigid instrument, internally cooled by circulating water, and designed for the optional use of two probes simultaneously. The SpineSTAR Ablation Instrument has a steerable

Global Approach to the Patient with Pain		
	Spinal	Non-spinal
Neoplastic	Radiofrequency Ablation Vertebral Augmentation Cryoablation	Ablative Techniques Catheter-Directed Therapy Cryoneurolysis
Non-neoplastic	Vertebral Augmentation Facet Block/Ablation Sacroiliac Block/ Ablation Intradiscal Therapy Nerve Root Block Epidural injection	Joint Injection Bursa Injection Peripheral Nerve Block Sympathetic Block Sympathetic Ablation Cryoneurolysis

Fig. 1 Global approach to the patient with pain.

flexible tip, allowing for varied ablation zones from a unipedicular approach. An illustrative case is shown in ►Fig. 3.

Nonspine Pain Related to Cancer

Our approach to a painful metastatic lesion outside of the spine is outlined in ►Fig. 4. Like the patient with potential spine involvement and pain related to cancer, our workup begins with examination of the patient and determination of

whether the chief complaint is referable to the lesion. Frequently, patients with metastatic disease are undergoing systemic therapy that may cause or worsen pain, they may have associated structural abnormalities that cause pain, or they may present with impressive imaging findings that do not translate to clinical complaints. Symptom correlation with imaging is a critical first step.

The next steps in the management of a patient with a nonspinal, cancer-related lesion that is causing pain are (1) determination as to whether or not the lesion can be safely accessed percutaneously under image guidance and (2) delineation of potential nontarget ablation structures along the access path or in proximity to the target lesion, inclusion of which would result in unwanted sequelae. Identification of critical adjacent structures leads to the utilization of adjunctive displacement techniques such as hydrodissection or pneumodissection, as well as attention to the extent and configuration of planned ablation zones.^{10,11}

Finally, once the access and adjacent structures have been cleared, the next question is whether the lesion is lytic or blastic. Blastic/sclerotic lesions often require adjustment of techniques such that either a separate outer needle is employed for access (such as the Osteo-Site, Cook Medical, Bloomington, IN) or a juxtacortical approach is used. In the latter, or for small lesions in difficult locations, cryoablation probes can be configured around a lesion such that the ablation zone extends to include the target (►Fig. 5). Lytic lesions at our institution are treated with one or more cryoablation probes such that the entirety of the neoplasm–bone or neoplasm–soft tissue interface is ablated (►Fig. 6). Cryoablation is our treatment of choice for painful metastatic osseous deposits not involving the spine because of the ability to visualize the ablation zone, ability to create variable ablation configurations and sizes using different probes, and improved analgesia compared with heat-mediated ablative systems.^{10,12–15} We do not routinely instill polymethylmethacrylate following palliative ablations. In our experience, the mass effect leads to slower recovery and may serve as a fulcrum for fracture.

Spine Pain that Is Unrelated to Cancer

Our algorithm for categorizing, diagnosing, and treating nonneoplastic spine pain is presented in ►Fig. 7. Each patient with spine-related symptoms that are not attributable to primary or metastatic neoplastic lesions is first evaluated for prior treatments, systemic medications, and history of complaint—and their description broadly classified as radicular or axial. It can be helpful to make this distinction by asking the patient, “If you could only treat one thing, would it be your back or your leg/arm?”

Radicular symptoms are often attributable to clear concordant imaging findings: for example, an L5 distribution pain syndrome in a patient with an edematous, bulging intervertebral disc at the appropriate level on the ipsilateral side to the complaint (►Fig. 8). If the patient's relief following a transforaminal injection is only temporary, either repeat injections in the same manner are performed (up to three in

Fig. 2 Algorithm for the evaluation of a painful metastatic lesion involving the spine.

Fig. 3 (a, b) Axial and sagittal CT images of a 57-year-old man with a history of lung cancer presenting with lumbar spine pain demonstrating lytic metastases involving L5 (arrows). (c) Intraprocedural anteroposterior (AP) image demonstrates a unipediculate coaxial, transpedicular approach from the left with a coaxially placed radiofrequency ablation probe (arrow) in the affected vertebral body. (d) Final image from RFA and cementoplasty demonstrates distribution of cement corresponding to the original lesion and fracture, providing stabilization.

Fig. 4 Algorithm for the evaluation of a painful metastatic lesion outside of the spine.

1 year), alternating midline epidural injections are performed (► **Fig. 9**), or a search for other underlying causes is undertaken. Important caveats to this approach are the use of CT and nonparticulate steroids in the cervical spine.^{16,17}

The causes for axial back pain are many, and can be grouped as potential targets for image-guided intervention. Facet syndrome, or symptoms attributable to hypertrophied, osteoarthritic facet articulations, most often includes band-like lower back pain and the absence of sitting pain in a patient with corresponding imaging findings. The facet articulations are supplied by branches of the adjacent dorsal rami nerves, the medial branch nerves—which are targeted for diagnostic and therapeutic injections, often followed by percutaneous denervation.¹⁸ Similarly, the lateral branches of the sacral nerves are amenable to rhizotomy using a percutaneous approach and image guidance.¹⁹

Importantly, each of these potential targets is first evaluated with a diagnostic injection of betamethasone and bupivacaine, with the expectation that multiple peripheral injections to the suspected pain generator on separate occasions (at least two) using different active agents in a comparative block fashion will predict response. That is, a true pain-generating target is expected to consistently yield substantial relief in pain symptoms when successfully

Fig. 5 Axial intraprocedural CT images demonstrate a proximal femoral osteoid osteoma (arrow) in a 29-year-old man (a), subsequent juxtacortical percutaneous image-guided placement of a 17-gauge cryoablation probe (b, arrow), and demonstration of target lesion inclusion by the visualized ablation zone (c, arrows).

blocked, and when different blocks are used, the relief in pain experienced from each should mimic their relative durations of effect.²⁰

Discogenic degenerative disease is a common cause for nonradicular lower back pain and is readily diagnosed with MRI. Although several percutaneous intradiscal therapies have evolved during recent years, no clear evidence exists

for their efficacy or role in standardized treatment.²¹ That said, many potential innovations are on the horizon, including intradiscal biological therapy (stem cells, platelet-rich plasma), ozone therapy, chemonucleolysis, decompression, laser therapy, drug delivery, and more.^{22–24} At present, procedural options for management of pain related to desiccated discs are limited to epidural injections.

Fig. 6 (a) A coronal fused image of a 71-year-old man with a history of non-small cell lung cancer and left chest wall pain demonstrates abnormal uptake of radiopharmaceutical about a left lateral rib (arrow), corresponding with his chief complaint. (b) Single axial intraprocedural CT image demonstrates placement of a 17-gauge cryoablation probe to the center of the lesion and the associated early ablation zone (arrow). In cases such as these, additional cryoablation probes or extension of freeze times are warranted to include the entirety of the lesion.

Fig. 7 An algorithm for the management of nonneoplastic spine pain.

Nonspine Pain that Is Unrelated to Cancer

The application of advanced imaging guidance to interventional pain procedures affords operators enhanced precision, efficacy, and safety profiles.^{3,25–29} The interventional radiologist can

perform a wide variety of injections to treat nonspinal pain of nonneoplastic origin, targeting painful joints, bursae, peripheral nerves, and autonomic plexi.^{30–32} In addition, the implementation of ablative technologies can provide long-lasting relief in a variety of settings related to peripheral pain.^{33,34}

Fig. 8 (a) Single axial T2-weighted MRI image demonstrates a left-side L5 asymmetric partial intervertebral disc herniation (arrow), corresponding to the patients presenting complaint. (b) Corresponding intraprocedural fluoroscopic image from a left-side L5 transforaminal injection demonstrates contrast outlining the affected exiting nerve root (arrow), confirming appropriate needle position.

Fig. 9 (a) Single axial T1-weighted MRI image of the lumbar spine demonstrates the shape and location of the midline epidural space (arrow). (b) Corresponding intraprocedural fluoroscopic image demonstrates contrast outlining the midline epidural space (arrows), confirming appropriate needle position.

Fig. 10 Percutaneous cryoneurolysis algorithm.

For patients with refractory pain syndromes that can be managed temporarily with perineural injections, and for whom motor function is not affected or not needed (e.g., in the cases of preexisting weakness), cryoablation/cryo-

neurolysis may be considered (►**Fig. 10**). Cryoablation affects nerves by interrupting local signal transduction, as well as through effects on systemic pain syndrome maintenance.³⁵ Peripheral nerves regenerate following cryoablation, following a predictable sequence of Wallerian degeneration and Schwann cell-mediated clearance of debris, cell signaling, guidance, elongation, and remyelination—at a rate of approximately 1 mm/day.³⁶ The implications of this regeneration include recovery of mixed motor-sensory nerves that are inadvertently or intentionally included in the cryoablation zone, as well as potential return of symptoms over time for the treated patient.

Following positive response to a diagnostic block (either 50% pain relief or 3 cm on a visual analog scale), nerves may be targeted for cryoablation using imaging guidance. For example, in the setting of pudendal neuralgia, the potential space surrounding the pudendal nerve may be filled with a bupivacaine and betamethasone admixture using CT guidance for purposes of comparative block predictions. Following documentation of a positive response, a cryoablation probe is guided to a location adjacent to the nerve such that the ablation zone will extend to involve the target. At our center, we perform ablation for a single 4-minute freeze in these settings, followed by a 5-minute passive thaw cycle and gentle removal of the probe (►**Fig. 11**).

Fig. 11 (a) Relevant planning landmarks for intervention to the pudendal canal. Axial CT scan from diagnostic pudendal nerve injection procedure (left) and corresponding anatomical landmarks (right). (b) Single axial postprocedure CT image from a pudendal nerve infiltration, demonstrating fluid in the pudendal canal (arrow). (c) Corresponding image from the subsequent cryoablation procedure, demonstrating placement of a 17-gauge cryoablation probe (arrow) in the ischiofemoral fat adjacent to the nerve.

Fig. 12 (a) Relevant planning landmarks for intervention in the setting of refractory inguinodynia (left) and corresponding anatomical landmarks (right). (b) Preprocedural T1 fat-saturated axial MR image from a patient with longstanding inguinodynia demonstrates fibrosis and stranding about the ilioinguinal and genitofemoral nerves (arrows), deep to implanted mesh. (c) Corresponding intraprocedural CT image from a cryoneurolysis procedure, demonstrating placement of the cryoablation probe (arrow) and warm saline protecting the overlying skin (arrowheads).

The approach to conditions such as pudendal neuralgia can be extrapolated to many other pain syndromes. For example, for patients with intractable pain related to prior hernia repair, a diagnostic injection is performed to infiltrate the offending nerves (in this case, the ilioinguinal and genitofemoral nerves) for diagnostic purposes. Following a positive response, the same sequence of events is undertaken as described for pudendal neuralgia (→ Fig. 12). Identification and evaluation of nerves responsible for refractory pain syndromes—and subsequent ablation or neuromodulation using advanced imaging guidance—is an open space for interventional radiologists to explore and impact. Additional examples include occipital neuralgia, other pelvic pain syndromes, phantom limb pain, postmastectomy pain syndrome, and other conditions amenable to denervation therapy (knee and/or hip osteoarthritis, pain in the saphenous nerve distribution, etc.).

Conclusion

The application of the interventional radiology skill set to pain management illuminates new opportunities to collaborate, innovate, and help human beings. The wide variety of potential interventions can be managed at the forefront by categorizing patient presentations into symptoms related to the spine and/or cancer, as detailed herein.

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