The Pain Crisis: Interventional Radiology's Role in Pain Management

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Pain is a complex syndrome that is difficult to treat. The increasing numbers of patients living with chronic diseases has led to increasing pain management needs and the rise of opioid use disorder (OUD) as a major and potentially lethal public health concern. Treatment of chronic pain with prescription opioids alone is not always successful, and a multidisciplinary approach is paramount to address the needs of patients at risk of developing or suffering from OUD. Interventional radiologists trained to perform minimally invasive procedures with negligible downtime and postprocedure pain can help stem the tide of opioid-related deaths and disability. This article reviews a wide range of minimally invasive procedures, including vertebral augmentation, sacroplasty, thermal ablation of osseous metastasis, nerve blocks, and gonadal vein embolization, that interventional radiologists are now using successfully to treat chronic pain. The evidence to support use of such procedures is highlighted. This article also briefly discusses emerging techniques such as arterial embolization and ablation for knee and shoulder osteoarthritis that have not yet been fully tested but exhibit strong potential in chronic pain management. By reducing opioid use in patients suffering from chronic pain, these minimally invasive procedures can potentially prevent escalation to OUD.

The need for pain management is growing given increasing numbers of patients living with chronic diseases such as malignancy, osteoporosis, and osteoarthritis. However, pain is a complex syndrome that is difficult to treat, in large part from confounding mental health conditions (e.g., depression), disability, and social factors such as unemployment and availability of medical resources and personnel. This challenge in chronic pain management has contributed to a rise in opioid use disorder (OUD) as a major and potentially lethal public health concern. Indeed, in the past 2 decades, a steep increase in opioid-related deaths has occurred in the United States. From 1999 to 2011, the annual number of deaths related to prescription opioid overdose tripled [1, 2]. Between 2011 and 2015, overdose deaths from illicit opioids, including heroin and synthetic opioids such as fentanyl, nearly tripled as people who started on prescription opioids began abusing these drugs [1, 2]. Currently, drug overdose is the leading cause of unintentional injury death in the United States, and opioids are responsible for most of these deaths. As of 2015, nearly 2.0 million Americans had an OUD associated with prescription opioids [1, 2]. Lawfully dispensed opioids also make their way into illicit markets, which contribute to a vicious cycle of increased use, crime, unemployment, homelessness, and mental health conditions, contributing in turn to further OUD [1, 2].

Treatment of chronic pain with prescription opioids alone is not always successful, and a multidisciplinary approach is paramount to address the needs of patients at risk of developing or suffering from OUD [3]. The WHO revised its analgesic ladder recommendations to include minimally invasive pain procedures if weak opioids or nonopioids were not effective in chronic noncancer pain situations [4]. This review discusses minimally invasive procedures performed by interventional radiologists intended to help reduce opioid use in patients suffering from chronic pain and potentially prevent escalation to OUD [5–7].

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Vertebral Augmentation

Vertebral fragility fractures or vertebral compression fractures are frequent in women after menopause but also occur in men and younger patients with risk factors for bone fragility [8]. A majority of vertebral fractures are asymptomatic, but some cause debilitating pain [9]. Nonsurgical management of vertebral compression fractures includes a combination of bed rest, spine support, and pain medications including narcotics. However, if the pain does not resolve in a few weeks, these patients are at risk for OUD. In addition, the combination of prolonged bed rest and opioid use increases risk of complications including constipation, pulmonary embolism, delirium or confusion, and death [10, 11].

Vertebral augmentation (VA) includes both vertebroplasty and kyphoplasty. Vertebroplasty involves injection of polymethylmethacrylate into a fractured vertebral body (Fig. 1). Kyphoplasty refers to inflation of high-pressure balloons within the collapsed vertebral body to restore vertebral body height and reduce kyphotic deformity followed by injection of polymethylmethacrylate (Fig. 1). The purpose of VA is to stabilize the fracture and restore spinal support, which in turn leads to a reduction in pain and improvement in quality of life. More recently, several vertebral implants including stents, jacks, cages, and fracture reduction systems have been used for VA [12]. However, there is no level 1 evidence to suggest that these implants improved outcomes compared with traditional VA in terms of pain or disability score reduction [13].

MRI of the spine is recommended before VA [14]. Edema of the vertebral body and spinal canal patency are well evaluated on MRI (Fig. 1). The presence of edema in the vertebral body increases the likelihood of postprocedural pain relief [14]. MRI can also exclude other conditions that may contribute to the patient’s pain, particularly malignancy and discitis-osteomyelitis, and helps in preprocedure planning. If the patient is unable to obtain an MRI, a bone scan with SPECT/CT should be obtained [14]. Fractures of the spine or elsewhere manifest as areas of increased tracer uptake on bone scan [15]. In addition to identifying endplate fractures and loss of vertebral body height, CT may show vacuum changes in the intervertebral disks, considered equivalent to the fluid cleft seen on MRI, a finding associated with improved pain after VA [16–18].

HIGHLIGHTS

Key Findings

- *Chronic pain is a complex syndrome that is difficult to treat and closely linked to opioid use disorder (OUD), a growing public health concern.*
- *Interventional radiologists who perform minimally invasive treatments for chronic pain are favorably suited to provide relief and circumvent the vicious cycle of OUD.*
- *Such procedures include vertebral augmentation, sacroplasty, thermal ablation of osseous metastasis, nerve blocks, gonadal vein embolization, and knee and shoulder embolization for osteoarthritis.*

VA is most often performed using biplane or single-plane fluoroscopy. A transpedicular or parapedicular approach, either bilateral or unilateral, can be used. Care should be taken not to violate the medial wall of the pedicle, which could damage the nerve roots or spinal cord and increase the risk of epidural extravasation of cement. The final position of the needle tip using a bilateral transpedicular approach should be overlying the anterior third of the vertebral body on the lateral view and directed toward midline on the anteroposterior view (Fig. 1).

Infection either at the operative site or in the blood stream is an absolute contraindication to VA. However, in such patients, VA may be considered after appropriate antibiotics [14]. The presence of coagulopathy, myelopathy, neural impingement, and spinal instability are relative contraindications [14]. Some of the complications of the procedure include spinal canal compromise from cement extravasation, osteomyelitis, cement toxicity, and pulmonary cement embolism [19].

TABLE 1: Randomized Controlled Trials Showing Negative Results for Vertebral Augmentation (VA) in Comparison With Sham Procedures

Study Characteristic	Kallmes et al. [22]	Buchbinder et al. [21]	Firanescu et al.[a] [23]
Inclusion criteria	Patients older than 50 y, < 3 VCFs between T4 and L5, VCF < 1 y in chronicity with pain score > 3 refractory to NSM	< 2 VCFs, pain refractory to NSM, radiographic evidence of VCF, VCF < 1 y in chronicity	Patients older than 50 y, < 3 VCFs, focal pain at the level of fracture, VAS score > 5, edema on MRI
Exclusion criteria	Neoplastic VCF, spinal canal compromise, active infection, coagulopathy	Neoplastic disease, neurologic deficit, osteoporotic VCF with > 90% collapse, spinal canal compromise	Cardiopulmonary morbidity, untreatable coagulopathy, systemic or local spine infection, neurologic symptoms
Sample size	68 in VA group and 63 in sham group	38 in VA group and 40 in sham group	91 in VA group and 89 in sham group
Endpoints	RDQ assessment, pain scale of 0–10	Pain scale of 0–10	Change in mean VAS score between the two groups
Outcomes	Not statistically significant difference in RDQ between groups, no significant improvement in pain score between groups	No statistically significant difference in pain scores between groups	No statistically significant difference in pain relief between groups

Note—VCF = vertebral compression fracture, NSM = nonsurgical management, VAS = visual analog score, RDQ = Roland-Morris disability questionnaire.

[a] VERTOS IV study.

Several studies have questioned the benefit of performing VA as opposed to conservative management in the setting of a vertebral fragility fracture, including the latest VERTOS IV trial [20–23] (Table 1). However, the methodologies of these studies, including the study design, sample size, and inclusion and exclusion criteria, have been criticized, thereby questioning the studies' validity [20, 24]. On the other hand, well-designed randomized controlled trials (RCTs) have shown a clear benefit for VA in the setting of intractable pain from a vertebral fragility fracture not responding to conservative management [7, 20, 25–28] (Table 2). A large retrospective review of the Medicare claims data for vertebral fragility fractures reported significantly increased mortality risk for patients treated nonoperatively when compared with those treated with VA [10].

The debate as to whether VA provides substantial benefit for patients with vertebral fragility fractures over nonsurgical management is ongoing, and there is a lack of clear consensus regarding the role of VA in vertebral fragility fractures. To provide a clear and comprehensive clinical pathway for the management of vertebral fragility fractures, a multidisciplinary expert panel assessed the appropriateness of VA in various clinical scenarios and endorsed VA for patients experiencing severe pain from an acute fragility fracture, progressive height loss, worsening spinal deformity, or inability to perform activities of daily living [14].

A couple of studies have suggested an increased risk of adjacent level fracture after VA [29, 30]. However, RCTs comparing VA and nonsurgical management showed no significant difference in the incidence of adjacent level fractures in patients who underwent VA [23, 25, 26, 31, 32]. One of the RCTs actually showed an increased incidence of adjacent level fractures in the conservative group compared with the VA group [25]. Further, vertebral fragility fractures tend to cluster in the same spinal segment, which may explain the apparent increase in adjacent-level fractures in patients undergoing VA.

Sacroplasty

Sacral fractures are underdiagnosed and undertreated [33]. The rate of sacral insufficiency fractures in patients 55 years old or older who present with back pain is approximately 1.8% [34]. Osteoporosis is a major risk factor, as are other causes of osteopenia including radiation to the pelvis, steroid use, and lytic sacral tumors [34]. Prolonged immobility from sacral insufficiency fractures causes substantial financial cost to the health care system, along with long-term disability and pain for the patient.

Bone scan and MRI both have a high sensitivity in the detection of sacral fracture. However, MRI offers the advantage of identifying alternative causes for pain [34]. Edema within the sacrum is best illustrated on fat-suppressed T2-weighted MRI or STIR images, and the fracture line is best seen on non–fat-suppressed T1-weighted images [34] (Fig. 2). Sacroplasty is usually performed in the prone position using CT guidance. Long-axis, short-axis, or oblique approaches can be used. At our institution, we typically

TABLE 2: Randomized Controlled Trials Showing Positive Results for Vertebral Augmentation (VA) in Comparison With Nonsurgical Management (NSM)

First Author [Reference]	Inclusion Criteria	Exclusion Criteria	No. of Patients	Endpoints	Outcome
Klazen[a] [26]	Patients older than 50 y, VCF at T5 or below, pain of > 5 on VAS for < 6 wk, edema on MRI	Severe cardiopulmonary comorbidity, coagulopathy, systemic or local spine infection or malignancy, neurologic symptoms	86 in VA group 77 in NSM group	Pain relief (VAS)	Significant decrease in mean VAS score in the VA arm compared with NSM arm
Farrokhi [25]	VCF with refractory pain of > 4 wk but < 1 y, focal tenderness related to VCF	Coagulopathy, local or systemic infection	40 in VA group 42 in NSM group	Pain relief (VAS), QoL (ODI)	Statistically significant reduction in pain score in VA group at 1 wk and 6-mo follow-up, higher QoL index reduction in the VA group than in NSM group
Blasco [27]	Acute VCF from T4-L5 with clinical onset < 12 mo, edema on MRI with 20% reduction in vertebral height or activity on bone scan	Untreatable coagulopathy, local or systemic infection, concurrent malignancy, spinal canal compromise	64 in VA group 61 in NSM group	Pain relief (VAS), QoL measures (Qualeffo-41)	Greater reduction in VAS scores in VA group compared with NSM group, VA group had significant improvement in Qualeffo-41 score
Chen [28]	Presence of acute VCF on MRI, persistent pain for at least 3 months	None	46 in VA group 43 in NSM group	Pain relief (VAS), functional outcome (ODI)	VA group had significantly greater pain relief than NSM, significantly greater improvement in ODI scores in VA group than in NSM group
Clark[b] [7]	Patients older than 60 y, back pain of less than 6 wk duration, NRS pain score of > 7/10, MRI confirming acute fracture	NRS pain < 7/10, delirium or dementia, MRI contraindicated, chronic pain, active cancer, or myeloma	61 in VA group 59 in placebo group	Proportion of patients with pain below 4/10 (NRS) at 14 days postintervention	44% with pain below 4/10 in VA group vs 21% in control group

Note—VCF = vertebral compression fracture, VAS = visual analog score, QoL = quality of life, ODI = Oswestry lower back pain disability index, Qualeffo-41 = quality of life questionnaire developed by the International Osteoporosis Foundation, NRS = numeric rating scale.

[a] VERTOS II study.

[b] VAPOR study.

TABLE 3: Summary of Thermal Ablation Studies to Treat Painful Bone Metastasis

First Author [Reference]	Treatment	No. of Patients	Pain Scale Type	Pain Scale At Baseline	Pain Scale 4–12 wk	Complications (No. of Patients)
Callstrom [54]	RFA	12	BPI-SF	8.0	1.0	Grade II skin burn (1), early postprocedural pain (9), late postprocedural pain after discharge (3), pneumonia (1)
Goetz [55]	RFA	43	BPI-SF	7.9	3.0	Grade II skin burn (1), transient bowel and bladder incontinence (1), acetabular fracture (1)
Dupuy[a] [56]	RFA	55	100 point	5.4	4.5	Foot drop (1)
Kastler [59]	MWA	17	VAS	7.4	2.2	No adverse events
Gianfelice [58]	MRgFUS	11	VAS	6.5	0.5	No adverse events
Callstrom [52]	CA	61	BPI-SF	7.1	1.4	No adverse events
Tomasian [57]	CA	14	NRS	8.0	3.0	Postprocedural radicular lower extremity nerve pain (2)
Wallace [53]	CA	56	NRS	8.0	4.5	Minimally displaced rib fracture, hemothorax (2), foot drop (1)

Note—Pain scale numbered 0–10. RFA = radiofrequency ablation, BPI-SF = Brief Pain Inventory (Short Form), MWA = microwave ablation, VAS = visual analog score, MRgFUS = MRI-guided focused ultrasound, CA =cryoablation, NRS = numeric rating scale.

[a] Dupuy et al. data were provided using a 100-point scale and converted to a 10-point scale for consistency.

use the oblique approach, which involves positioning the needle slightly oblique to the long axis of the sacrum to maximize cement filling of the fracture line (Fig. 3). Complications and contraindications are similar to VA procedures.

There are no RCTs (level 1 evidence) to favor sacroplasty over conservative treatment in the management of these fractures. Most of the data for sacroplasty comes from case series and retrospective or observational studies [35–37]. More recently, a systematic review and meta-analysis of all studies involving sacroplasty concluded that sacroplasty is safe and effective for treatment of sacral insufficiency fractures and provides long-term pain relief [38].

Thermal Ablation and Cementoplasty for Metastatic Bone Tumors

Approximately 80% of patients with cancer will develop bone metastases, with lung, breast, and prostate cancers the most frequent primary lesions [39]. Osseous metastases often reduce patient performance status and quality of life because of impaired mobility, intractable pain, and pathologic fractures [39]. Osseous metastases are usually treated with a combination of analgesic medications, bisphosphonates, and systemic chemotherapy or hormonal therapy targeted to the primary tumor. Despite high doses of opioid analgesics, some patients experience no or suboptimal pain relief and may suffer side effects of these medications. In such patients, radiation therapy (RT) remains the standard treatment. RT can achieve pain relief in approximately 60% of patients. However, pain relief is often temporary and, in some patients, it may be weeks before substantial improvement is obtained [40]. Thermal ablation (TA) has been effectively used in palliation of painful osseous metastasis with a much shorter response time [41]. In fact, in a recent study cryoablation was a cost-effective alternative for recurrent pain after RT with much quicker pain relief [42]. To our knowledge, no study has directly compared the effectiveness of RT and TA in treatment and palliation of osseous metastasis. However, a couple of studies report that the combination of the two modalities results in better local control and pain relief than the two therapies used individually [43, 44]. Palliative TA for painful metastasis is indicated in patients with at least moderate pain that corresponds to the site of disease [19] (Fig. 4).

CT or MRI should be obtained before treatment to accurately assess the extent of disease, integrity of the surrounding cortical or subchondral bone, and proximity to neurovascular and other critical structures (Fig. 5). Osteolytic, mixed osteolytic-osteoblastic, or osseous tumors with a predominant soft-tissue component are best suited for TA [19]. Although radiofrequency ablation (RFA) is the most widely adopted modality for TA in osseous metastases, the ablation margins cannot be well seen on imaging and multiple overlapping ablations may be needed to treat large lesions [19] (Fig. 4). Additionally, RFA is more painful, necessitating the use of general anesthesia [45, 46]. Cryoablation has several advantages over RFA in the treatment of osseous metastases, including the ability to simultaneously use multiple probes to create a larger confluent ablation zone, better visualization of the ablation zone or ice ball on imaging, and less intraprocedural pain that allows treatment under conscious sedation rather than general anesthesia [35, 45, 47] (Fig. 5). CT guidance is used for probe placement in the treatment of most extraspinal metastatic bone tumors. The ablation probes may be placed directly into the lesion or through coaxial bone needles depending on the integrity of the overlying cortical bone. Uninsulated bone introducer needles should be sufficiently withdrawn during RFA to avoid inadvertent transmission of energy along the needle shaft (Fig. 4).

Ablation of metastases in axial load-bearing bones such as the spine and pelvis can be augmented by injecting polymethylmethacrylate both within and around the ablation zone (cementoplasty) to treat or prevent pathologic fractures [19] (Fig. 4). Pain relief after cementoplasty in the treatment of metastatic bone tumors can occur both from stabilization of microfractures and the toxic effect that the exothermic reaction of polymethylmethacrylate has on nociceptors [48].

TA and cementoplasty of osseous metastases are safe procedures with relatively low complication rates [19]. Complications from TA are often a result of unintended thermal injury to nearby structures such as nerves and skin [19]. Skin injuries from TA may be managed conservatively with topical use of silver sulfadiazine or bacitracin [49]. Neural injury after ablation of musculoskeletal tumors may occur as a result of the proximity of central and major peripheral neural structures to the target lesion, an outcome that may be unavoidable depending on the location of the tumor (Fig. 5). Inadvertent injury to other organs may also occur owing to use of sharp trocars and applicators and from collateral thermal injury. Several techniques, including fluid or gas dissection, balloon separation, heating or cooling systems, and temperature monitoring, have been reported to protect these critical structures from thermal damage [50, 51]. Potential complications of cementoplasty include infection, cement pulmonary embolism, and leakage of cement into the epidural space, neural foramina, other perineural locations, and joints [19].

Both RFA and cryoablation have been used for palliative treatment of painful metastasis in several single-arm observational studies [41, 47, 52–57] (Table 3). Data evaluating microwave ablation, laser ablation, and high-intensity focused ultrasound in osseous metastasis are limited [58, 59] (Table 3). A recent systematic review of the different TA modalities found no compelling indication of superiority of one technique over the others [60].

Nerve Blocks

Epidural Steroid Injection

Epidural steroid injection is one of the most common procedures performed in patients with back pain [61]. Between 2000 and 2008, there was a marked increase in epidural injections for management of chronic pain in the Medicare population, with a 108% increase in the number of patients receiving any spinal injection and a 253% increase in the number of epidural injections specifically [62]. Although use of epidural injections for management of chronic pain decreased from 2009 to 2018, back pain with or without radicular pain remains a major reason for disability and loss of productivity [63, 64]. Generally, patients with spinal stenosis, bilateral radicular pain, and/or multilevel degenerative disk disease receive an interlaminar epidural steroid injection [65] (Fig. 6). In patients with unilateral radicular pain that can be attributed to a single-level disk bulge or herniation, a transforaminal epidural approach is used [65] (Fig. 7). The caudal approach to epidural injection is typically performed in patients with back pain and extensive thoracolumbar fusion [65]. Meta-analyses of epidural steroid injections have shown benefit in the short term (< 3 months), although evidence of long-term benefit is variable [66, 67]. Despite recommendations to use image guidance and contrast administration to mitigate risk and ensure proper epidural needle placement, only a small minority (3%) of image-guided spine interventions, including epidural steroid injections, are performed by radiologists [68–70].

Epidural steroid injection may be performed using a variety of techniques and imaging modalities [61, 71]. Lumbar epidural injections are typically performed with fluoroscopic guidance [71]. Using CT fluoroscopy, the needle can be positioned more precisely and rapidly at the desired level, while identifying potential problems such as spinal stenosis and synovial cysts before needle insertion [71]. Radiation dose to the operator and patient is minimal when using CT fluoroscopy and a low tube current–exposure time setting [71]. Several publications describe the technical details and complications of epidural steroid injections [61, 65, 71].

Intercostal Nerve Block for Postthoracotomy Pain Syndrome

Postthoracotomy pain syndrome (PTPS) is persistent or recurrent pain for at least 2 months after thoracotomy and affects approximately 50% of patients after thoracotomy [46]. The pathogenesis remains unclear, but PTPS is most likely from

TABLE 4: Summary of Ovarian and Pelvic Vein Embolization Studies to Treat Pelvic Congestion Syndrome

First Author [Reference]	No. of Patients	Embolization Material	Mean Follow-Up (mo)	Baseline VAS	Follow-Up VAS	Positive Outcome (%)
Venbrux [88]	56	Coils and sclerosant	22.1	7.8	2.7	96
Chung [91]	52	Coils	6–12	7.8	3.2	100
Kim [86]	127	Coil and sclerosant	45	7.6	2.9	83
Kwon [6]	67	Coils	44.8	NA	NA	82
Monedero [90]	100	NA	14	NA	NA	64
Laborda [89]	202	Coils	60	7.3	0.78	93

Note—VAS = visual analog scale, NA = not available.

TABLE 5: Summary of Arterial Embolization Studies for Shoulder and Knee Pain

First Author [Reference]	Target	No. of Patients	Scale	Baseline	Follow-Up
Hwang [93]	Shoulder and elbow	13	VAS	6.3	2.0
Okuno [94]	Shoulder	25	VAS	8.2	0.8
Bagla [95]	Knee	20	VAS	7.6	2.9
Okuno [96]	Knee	72	WOMUO	12	2.6
Lee[a] [97]	Knee (mild to moderate)	59	VAS	5.5	1.9
Lee[a] [97]	Knee (severe)	12	VAS	6.3	5.9

Note—Pain scale numbered 0–10. VAS = visual analog scale, WOMUO = Western Ontario and McMaster Universities Osteoarthritis Index.

[a] For the Lee et al. study, patients were divided into two cohorts by Kellgren–Lawrence grade: mild-to-moderate osteoarthritis (Kellgren–Lawrence grade 1–3) and severe osteoarthritis (Kellgren–Lawrence grade 4).

a combination of neuropathic and myofascial pain related to intercostal nerve trauma [46]. Management of PTPS can be challenging and refractory to commonly recommended treatments including nonsteroidal antiinflammatory analgesics, opioids, gabapentin, antidepressants, and local or regional anesthesia [46]. PTPS can have a major impact on patient's productivity and mental health and increase the risk for depression and OUD [72].

Intercostal nerve cryoablation to temporarily impair nerve conduction rather than cause permanent nerve damage or injury has been shown to improve pain in patients with PTPS; the relief after ablation lasts for approximately 6–9 months in most patients [46]. Cryoablation is used instead of RFA given that cryoablation is better tolerated and less likely to cause neuroma formation [46]. The intercostal nerve is targeted at the inferior margin of the rib, and cryoablation is performed for 3 minutes at 60% of the power (Fig. 8). The technical details and complications from intercostal nerve cryoablation have been previously described [46].

Celiac Plexus Neurolysis

The celiac plexus is a network of ganglia located in the paraaortic region of the retroperitoneum at the level of the celiac axis, with sympathetic and parasympathetic efferent fibers and sensory afferent fibers from the upper abdominal viscera [73].

Celiac plexus neurolysis (CPN) is a palliative treatment option for patients with intractable upper abdominal pain, often from upper abdominal malignancies or chronic pancreatitis. Though used in both settings, CPN may be less helpful in pain relief for patients with chronic pancreatitis than with malignancy [5]. For example, a meta-analysis of endoscopic ultrasound-guided CPN reported response rates of 59% in chronic pancreatitis and 80% in pancreatic cancer [74].

CPN is most frequently performed using CT or endoscopic ultrasound guidance. The choice of image guidance is driven by referring provider preference, operator preference, and resource availability. CT guidance for CPN has several advantages, including accurate depiction of the needle trajectory, relationship to surrounding structures, anatomic variation in the region, and the extent of neurolytic spread, which has been shown to correlate with posttreatment response [75]. CPN is most frequently performed via an anterior or posterior approach, but lateral decubitus, posterior intradiscal, and transaortic approaches have been described [73]. Although some of these approaches require the needles to traverse critical structures, it is generally well tolerated. Using CT guidance, 22-gauge needles are placed approximately 1–2 cm anterior to the aorta between the celiac axis and superior mesenteric artery [73]. After this, 1% lidocaine mixed with a small amount of contrast material is injected to determine the region of opacification, ensure extravascular needle position, and assess whether the patient experiences pain relief from the lidocaine injection [73]. Confirmation of contrast material infiltrating around the celiac axis and lateral to the aorta is also desired (Fig. 9). CPN is then generally performed using absolute alcohol mixed with contrast material and 0.5% bupivacaine. The injection volumes vary but are typically in the range of 20–30 mL on each side [73].

Overall complication rate of CPN is less than 2% (77). Minor complications include temporary abdominal or back pain radiating to the shoulder, diarrhea, and orthostatic hypotension [73, 75]. Major complications from CPN, including retroperitoneal hematoma, abdominal aortic injury, chylothorax or pneumothorax, solid organ injury, and neurologic deficits, are extremely uncommon [75].

CPN improves quality of life and decreases narcotic use in 70–90% of patients with various abdominal cancers [73]. An RCT comparing CPN with medical management in patients with pancreatic cancer reported that patients who received CPN showed significant improvement in pain levels and decreased opioid use [75]. Studies have shown that patients with upper abdominal malignancies experience the most analgesic effect and better performance status and quality of life when CPN is performed early in the course of the disease [75–77]. This is most likely from the bulky abdominal disease burden in the later stages interfering with adequate spread of the neurolytic needed to damage the nerve fibers and produce a good clinical response [75].

Superior Hypogastric and Ganglion Impar Neurolysis

The superior hypogastric plexus is located anterior to the L5-S1 disk, and the ganglion impar is located anterior to the sacrococcygeal joint. These neural structures are involved in transmission of pain sensation from the pelvic organs. The pain associated with lower abdominal or pelvic malignancies can be treated with a combination of superior hypogastric and ganglion impar neurolysis. This can be performed from an anterior or posterior transdiscal approach. The ganglion impar can be targeted posteriorly through the sacrococcygeal joint [78].

Pelvic Venous Disorder

Chronic pelvic pain (CPP) is noncyclical pain felt in the pelvis, anterior abdominal wall, lower back, or buttocks for greater than a 6-month duration [79]. A recent systematic review reported the prevalence of CPP ranges from 6 to 27% [80]. This variation is probably a result of the inconsistency in defining CPP and failure to exclude dysmenorrhea [81]. Causes of CPP are endometriosis, pelvic inflammatory disease, and pelvic varicosities. In many instances, despite extensive workup, the cause of CPP remains elusive. Pelvic venous disorder, also known as pelvic congestion syndrome, is thought to relate to pelvic varicosities and accounts for approximately one-third of cases of CPP [82]. Pelvic venous disorder is a challenging disorder to diagnose given that pelvic varicosities have also been observed in women without symptoms [82]. The challenge in diagnosing this condition may contribute to the mixed results after ovarian vein embolization, which is the endovascular treatment of intractable pelvic venous disorder [82, 83].

Most women affected by pelvic venous disorder are of childbearing age and present with noncyclic pelvic pain, usually described as a persistent dull ache or fullness and often exacerbated by prolonged standing, coitus, and pregnancy. Other symptoms include hematuria, headache, bloating, nausea, vaginal discharge, vulvar swelling, feeling of leg fullness, lower backache, rectal discomfort, urinary urgency, generalized lethargy, and depression [82].

Imaging helps to identify the patients who may benefit most from gonadal vein embolization. Ultrasound in these patients typically shows dilated ovarian veins greater than 8 mm in diameter with slowed or reversed blood flow, dilated arcuate veins communicating with bilateral pelvic varicosities across the myometrium, and/or associated polycystic ovaries [83] (Fig. 10). On CT and MRI, ovarian vein diameter greater than 8 mm supports a diagnosis of pelvic venous disorder in the appropriate setting [83] (Fig. 10). The presence of severe labial, perineal, or lower extremity varicosities further supports the diagnosis of pelvic venous disorder [83].

The basic abnormality in pelvic venous disorder is venous distention and engorgement from varied causes which may activate specific pain receptors within the venous walls, causing a diffuse ache [83]. Gabapentin and amitriptyline are more effective than opioid or nonsteroidal analgesia at relieving pelvic pain in pelvic venous disorder [83]. Medical management with medroxyprogesterone acetate or gonadotropin-releasing hormone analog may provide temporary relief [82].

Gonadal vein embolization is typically performed after failed medical management. Venographic diagnostic criteria for pelvic venous incompetence, which should be established before embolization, include ovarian vein diameter greater than 10 mm and congestion of the ovarian, pelvic, vulvovaginal or thigh veins, with retrograde flow [83] (Fig. 11). Additionally, a left renocaval pressure gradient greater than 4 mm Hg may suggest concomitant renal vein compression contributing to left ovarian vein dilation, especially if associated with collateral venous outflow on left renal venography. In that setting, gonadal embolization should be performed only after careful consideration of the potential to exacerbate left renal venous hypertension [84].

The femoral or jugular vein may be accessed for the procedure. The gonadal vein should be embolized along its entire length to prevent residual incompetent patent segments from collateralizing with retroperitoneal veins and reestablishing the reflux circuit [85] (Fig. 11). Because of the communications that exist between the internal iliac vein tributaries and the ovarian veins, selective venography of both the internal iliac veins is recommended [85, 86]. Criteria for internal iliac vein incompetence include reflux into the ipsilateral or contralateral proximal thigh, filling of the main trunk of the internal iliac vein and at least one side branch (gluteal, ischial, or obturator), and flow across the midline [87]. Balloon occlusion venography of the internal iliac veins and its branches is used to map the complex venous anatomy in patients with pelvic venous disorder and also for sclerosis or embolization of the incompetent veins [85]. A variety of agents can be used for embolizing the gonadal veins, including vascular plugs, coils, glue, gelatin sponge, or foam sclerosants [85] (Fig. 11). These can be used individually or in combination. The sandwich technique in which a foam sclerosant is injected between coils or plug occluders at various segments of the ovarian vein is quite common [85]. Embolization of pelvic varicosities arising from the internal iliac vein is typically performed using foam sclerosants without mechanical occlusion. The sclerosant is injected during balloon occlusion of the targeted branch and allowed to dwell for 5–10 minutes before the balloon is deflated [86].

Several single-arm prospective observational studies with sample sizes ranging from 50 to 200 patients and follow-up periods ranging from 20 to 72 months have evaluated the outcomes of patients who underwent pelvic vein embolization for pelvic venous disorder [6, 86–90]. These studies showed pain relief in 60–100% of patients (Table 4). Additionally, an RCT showed that pelvic vein embolization for pelvic venous disorder provided superior pain relief when compared with hysterectomy and oophorectomy [91].

Emerging Use of Ablation and Embolization in the Knee and Shoulder

RFA to treat chronic knee pain from osteoarthritis by targeting genicular nerves (neuromodulation) was first described in 2011 [92]. Eight RCTs studied RFA in chronic knee pain, six of which compared knee RFA to sham or other accepted treatments [92]. Extreme heterogeneity and variations in the prior studies make the accumulated data difficult to interpret. However, the results of these studies suggest that radiofrequency denervation can be a safe and effective treatment of chronic knee pain from osteoarthritis, with the duration of benefit ranging from 3 to 12 months [92]. Further research is needed to better identify neural targets, optimize treatment parameters, and better show relative effectiveness compared with other treatments.

Angiogenesis is known to contribute to chronic pain in osteoarthritis by enabling growth of new unmyelinated sensory nerves along their path [93]. Histopathologic studies have shown the existence of abnormal vessels accompanying nerve fibers in tissues from various painful conditions, including osteoarthritis and frozen shoulder [93, 94]. This is the premise for performing transcatheter arterial embolization around the knee and shoulder using antibiotic agents (imipenem and cilastatin sodium) or permanent embolic microspheres (100–75 μm) [93, 95] (Fig. 12). Imipenem and cilastatin sodium is an approved antibiotic and forms 10–70 μm insoluble particles when suspended in contrast material, allowing embolization of small vessels [93, 94]. Some authors consider it to be safer than the conventional microsphere embolic agents [93, 94]. Studies have reported positive clinical outcomes for such procedures [93–98] (Table 5). Long-term follow-up of up to 2 years has shown sustained pain relief and no ischemic complications in the bones and muscles after embolization, as assessed by MRI [96]. Transient skin changes without long-lasting consequences, presumably from occlusion of the skin capillaries, has been reported with the use of permanent embolic microspheres and not with the antibiotic suspension [93, 95]. These minimally invasive procedures are intended to prevent or prolong the need for major operations such as knee replacement or manipulation under anesthesia for frozen shoulder. These new procedures appear to be safe and effective for providing pain relief in various retrospective and prospective single-arm nonrandomized studies. However, before the procedures are used broadly in the general population, their efficacy needs to be established through well-designed RCTs.

Conclusion

Chronic pain is a complex syndrome that is difficult to manage. The highly specialized nature of the modern health care system risks fragmentation in care. Patients with chronic pain would thus benefit from a comprehensive multidisciplinary approach to pain management that includes palliative care, pain medicine, radiation oncology, and interventional radiology. Interventional radiologists performing minimally invasive procedures to treat chronic pain are favorably suited to provide relief for these patients and circumvent the vicious cycle of OUD.

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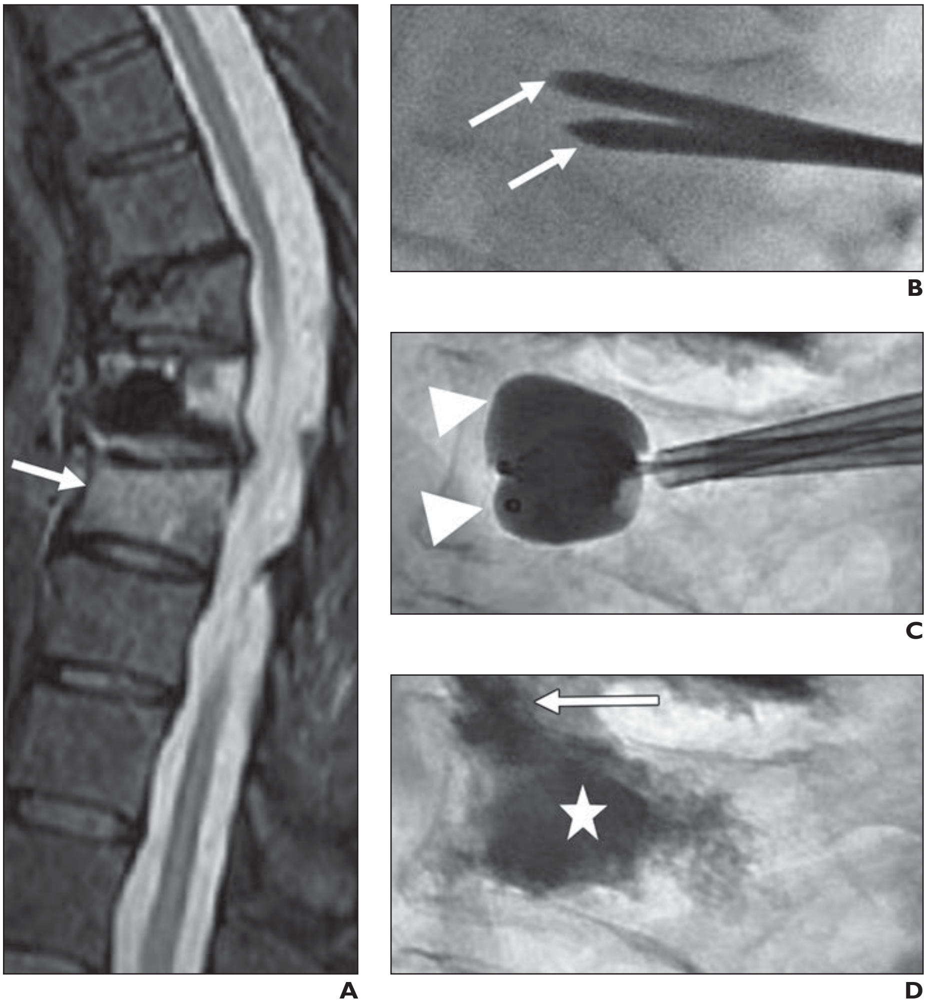

Fig. 1—Vertebral compression fracture and kyphoplasty in 70-year-old woman with mid back pain.

A, Fat-saturated sagittal T2-weighted MRI of thoracic spine shows edema in T8 vertebral body (*arrow*) with mild compression, suggestive of acute fracture.

B–D, Intraprocedural lateral spot fluoroscopic images of T8 vertebral body show needle tips (*arrows*, **B**) at junction of anterior and middle thirds of vertebral body, balloons fully inflated (*arrowheads*, **C**), and adequate amount of cement in vertebral body (*star*, **D**). Minimal cement extravasation into disk space (*arrow*, **D**) is seen, which is usually inconsequential.

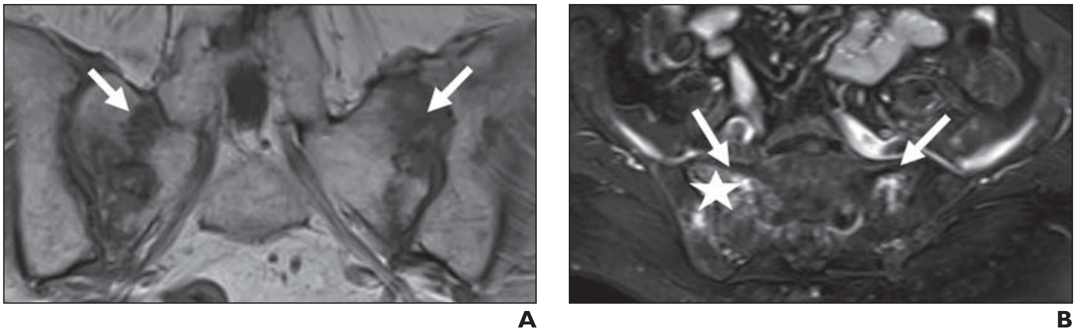

Fig. 2—Sacral insufficiency fractures in 80-year-old woman with bilateral hip pain.
A and **B,** Coronal T1-weighted (**A**) and axial fat-saturated T2-weighted (**B**) MR images of sacrum show bilateral fracture lines in sacral ala (right greater than left) (*arrows*). Axial fat-saturated MRI of sacrum shows edema in right sacral ala (*star*, **B**), indicating acute component.

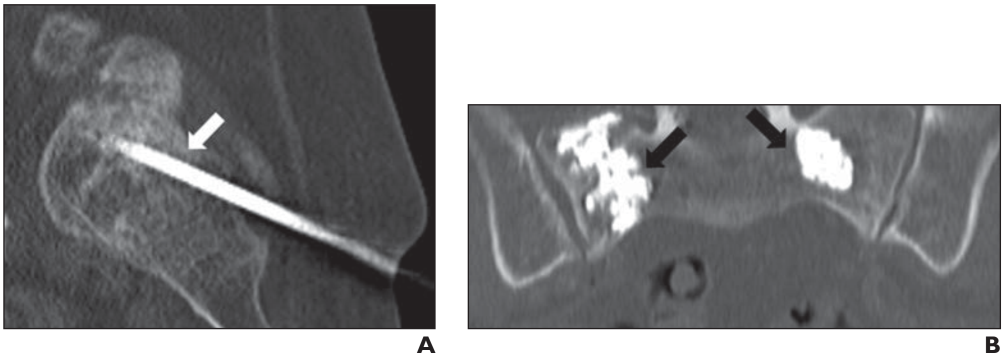

Fig. 3—Sacroplasty in 80-year-old woman with bilateral hip pain (same patient as Fig. 2).
A, Sagittal CT of sacrum shows needle (*arrow*) in sacral ala.
B, Coronal CT of sacrum after sacroplasty shows adequate cement filling (*arrows*).

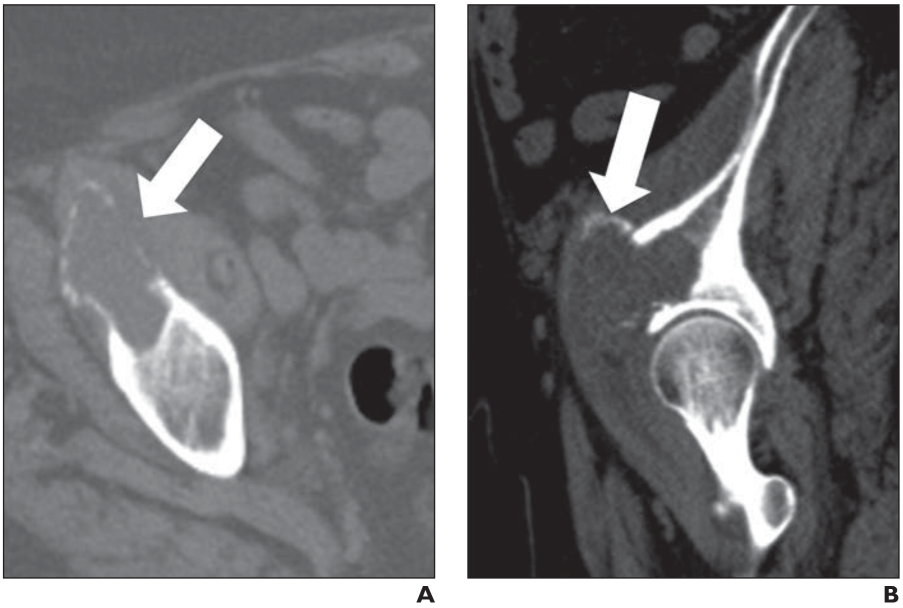

Fig. 4—Radiofrequency ablation (RFA) and cementoplasty of iliac bone metastasis in 65-year-old woman.
A and **B,** Axial (**A**) and sagittal (**B**) CT images show lytic area (*arrow*) from metastatic renal cell cancer in anterior aspect of right iliac bone.

(Fig. 4 continues on next page)

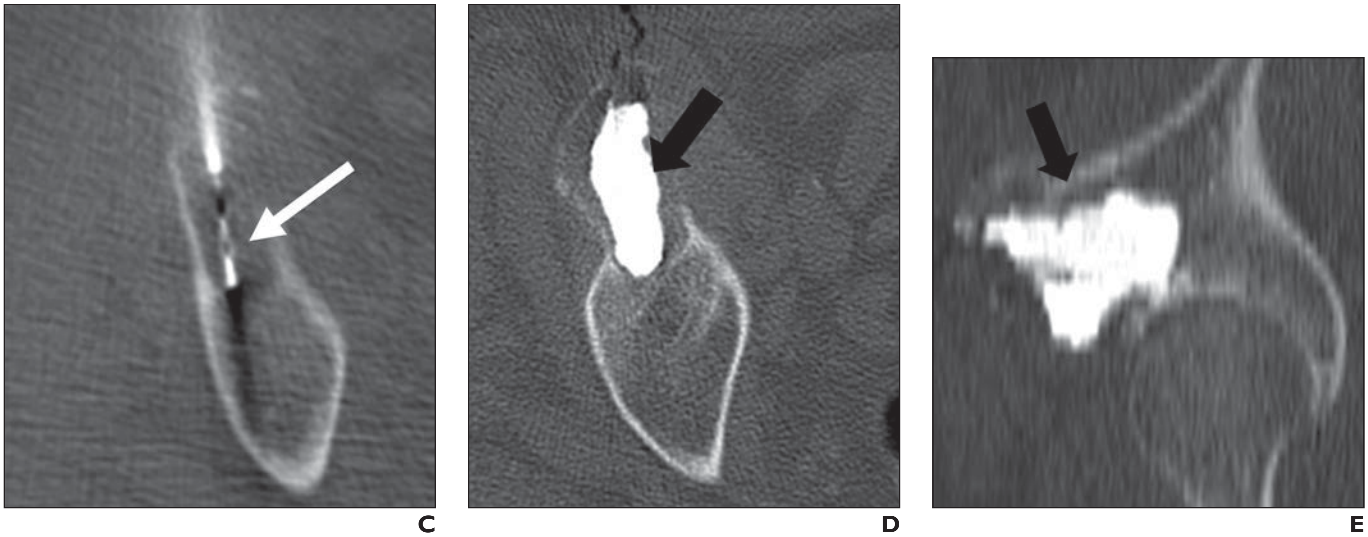

Fig. 4 (continued)—Radiofrequency ablation (RFA) and cementoplasty of iliac bone metastasis in 65-year-old woman.
C, Axial procedural CT shows access needle and radiofrequency probe (*arrow*) within lytic area.
D and **E,** After RFA and cementoplasty, axial (**D**) and sagittal (**E**) CT images show adequate cement filling lytic area (*arrow*).

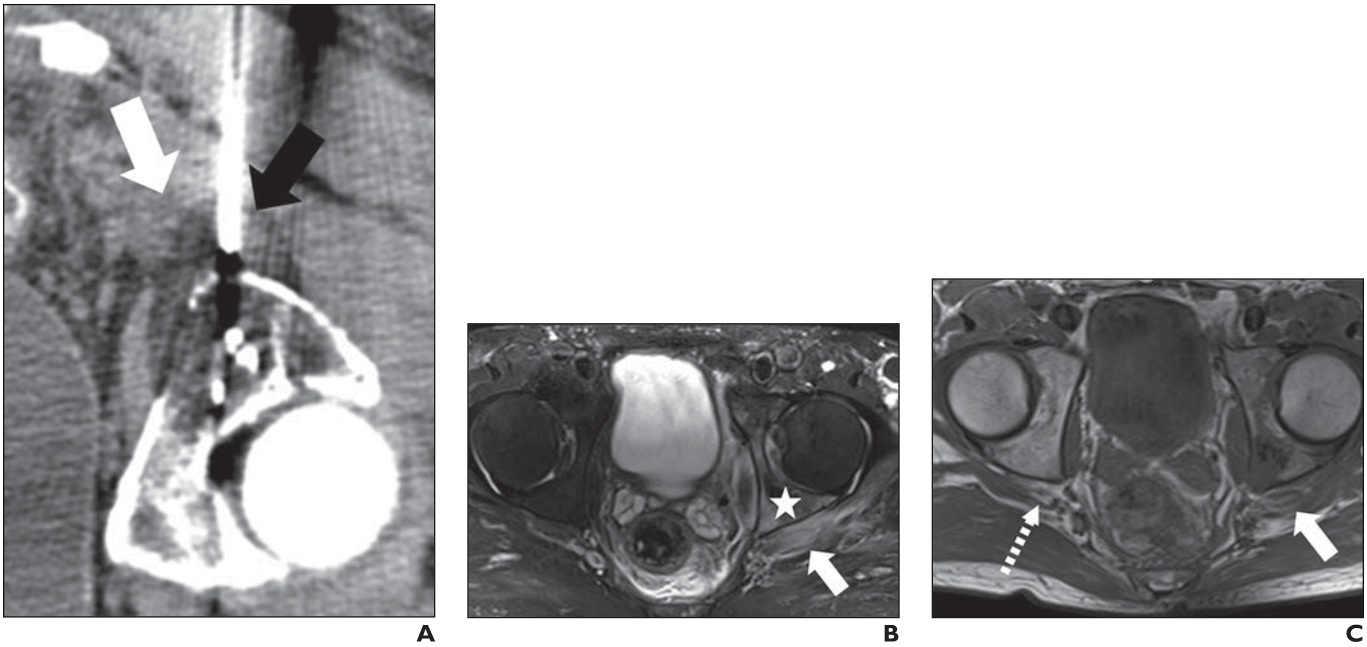

Fig. 5—Cryoablation and nerve damage in 69-year-old man.
A, Axial CT during cryoablation of left hip lesion shows ice ball (*black arrow*) close to sciatic nerve (*white arrow*).
B and **C,** Axial fat-saturated T2-weighted (**B**) and T1-weighted (**C**) MR images of pelvis show thickened nerve (*solid arrow*) from inflammation. Normal right sciatic nerve (*dashed arrow*, **C**) is shown for comparison. Treated lesion (*star,* **B**) is hyperintense on fat-saturated T2-weighted image.

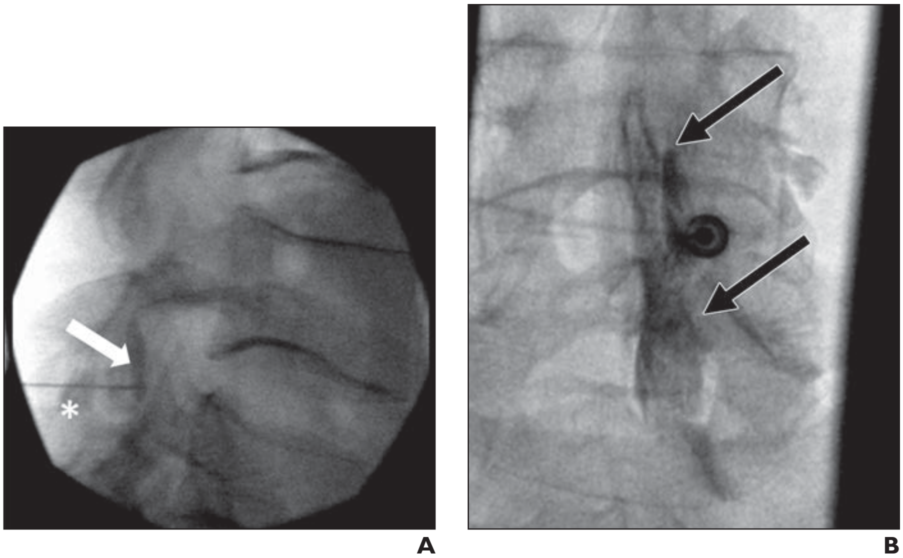

Fig. 6—53-year-old man with low back pain and bilateral lower extremity radicular pain.
A, Lateral fluoroscopic image of lumbar spine shows contrast material in epidural space (*arrow*) and extravasated contrast material in posterior soft tissues (*asterisk*).
B, Subsequent prone anteroposterior fluoroscopic image shows eccentric right-sided contrast material spread (*arrows*) confirming epidural location.

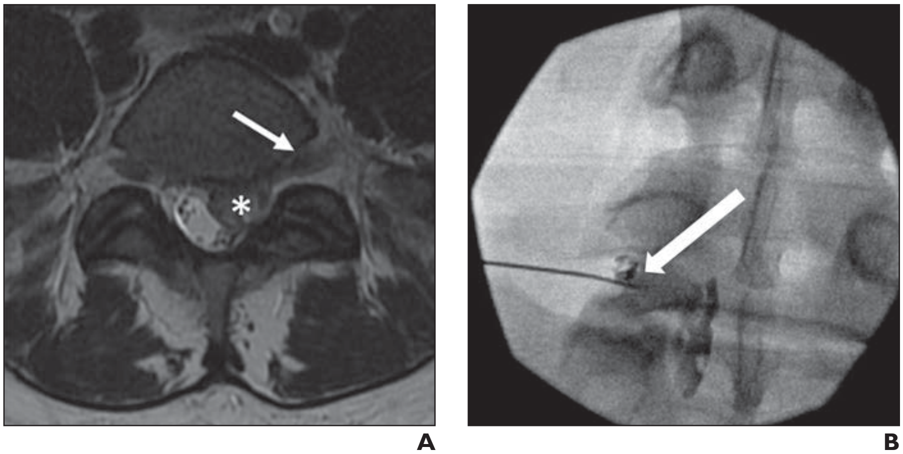

Fig. 7—34-year-old woman with left L5 radicular pain.
A, Oblique axial T2-weighted image shows large subarticular disk extrusion (*asterisk*) contacting left L5 nerve root (*arrow*).
B, Oblique fluoroscopic image from left L5-S1 transforaminal epidural steroid injection with patient in prone position shows injection of 1 mL iodinated contrast material, which confirms epidural location of needle tip (*arrow*).

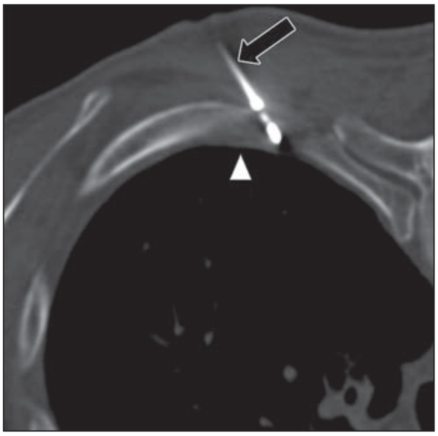

Fig. 8—Cryoablation for postthoracotomy pain syndrome in 45-year-old man. Axial procedural CT of chest shows cryoprobe (*arrow*) at inferior rib margin, positioned just short of pleural line (*arrowhead*).

Fig. 9—Celiac plexus neurolysis in 65-year-old woman with pancreatic cancer. CT of abdomen in prone position after injection shows combination of contrast material and alcohol (*arrows*) in vicinity of celiac plexus along lateral aspect of aorta.

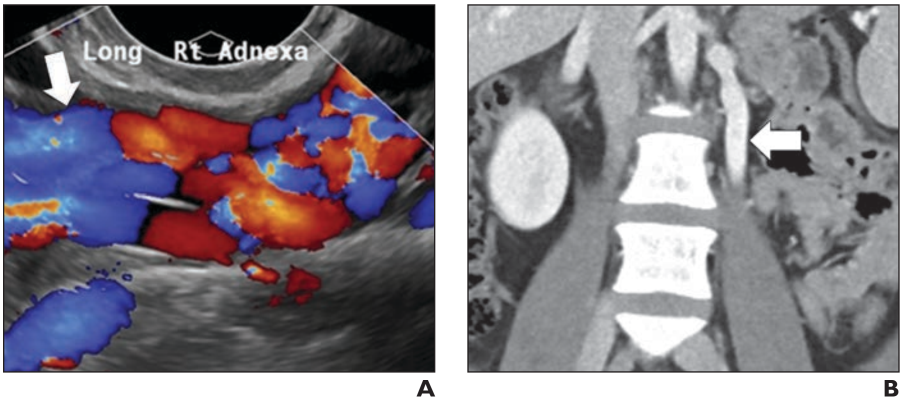

Fig. 10—40-year-old woman with pelvic venous disorder.
A, Color Doppler ultrasound of pelvis shows multiple dilated pelvic veins (*arrow*). Rt = right.
B, Coronal reformatted CT of abdomen shows dilated left gonadal vein (*arrow*).

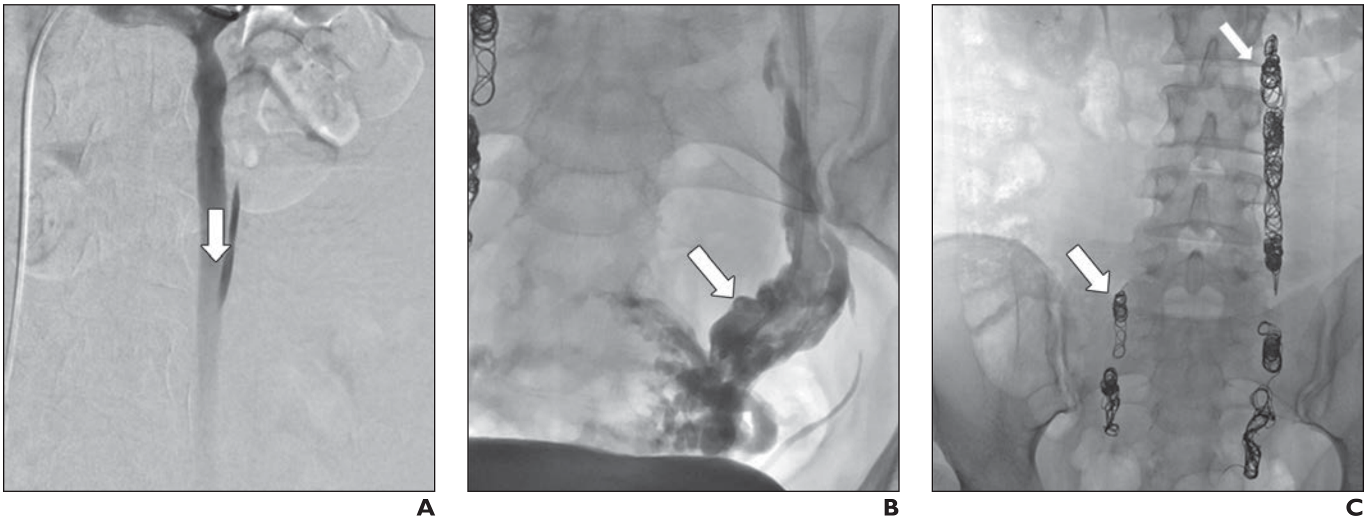

Fig. 11—Gonadal vein embolization for pelvic venous disorder in 40-year-old woman.
A, Digital subtraction venography of left gonadal vein with catheter at renal confluence (*arrow*) shows retrograde flow of contrast.
B, Digital subtraction venogram of pelvis shows dilated engorged pelvic veins (*arrow*) from venous incompetence.
C, Fluoroscopic anteroposterior image of abdomen and pelvis after embolization of both gonadal veins shows coils (*arrows*) along course of bilateral gonadal veins.

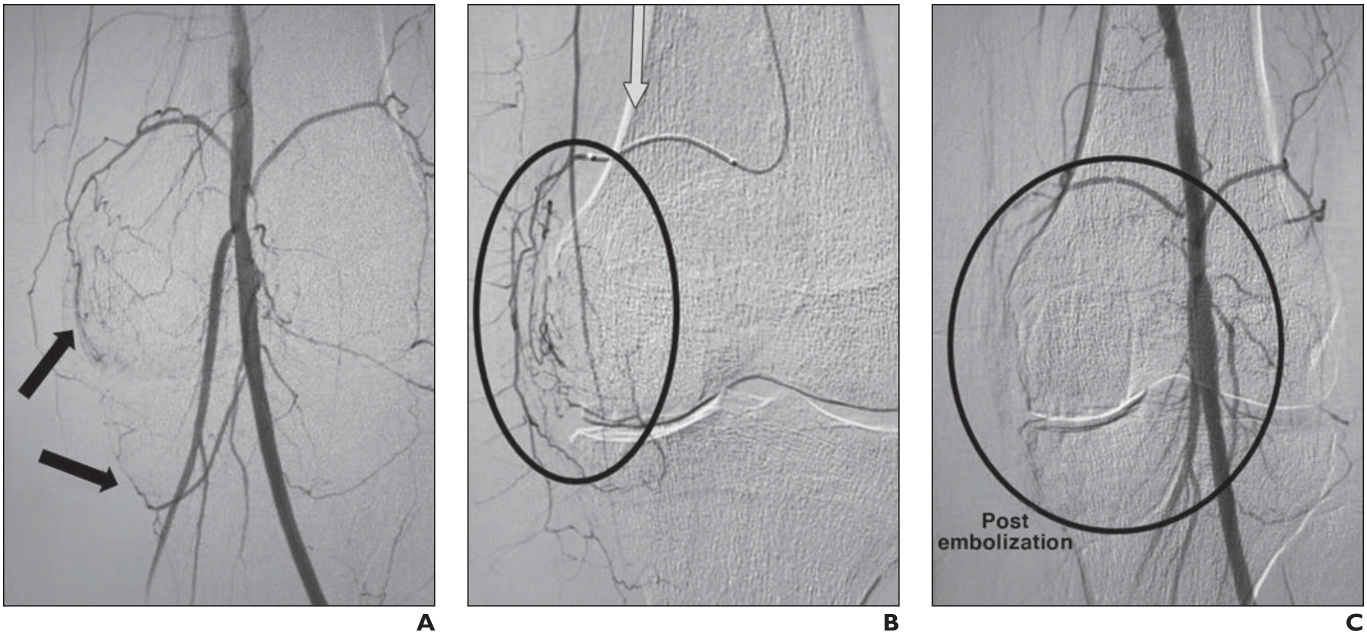

Fig. 12—67-year-old man with medial knee pain, not responding to pain medication. (Courtesy of Tummala V, Lakeland Vascular Institute, Lakeland, FL)
A, Preembolization image of knee shows abnormal vascularity (*arrows*) in medial aspect of knee.
B, Subselective catheterization of superior medial genicular branch of knee with microcatheter (*arrow*) shows abnormal vascularity in medial more conspicuously (*oval*).
C, Image after embolization shows clearing of abnormal vascularity (*circle*) in medial aspect of knee. Patient felt immediate pain relief.