Emerging Imaging Tools for Interventional Pain

55

Marc A. Huntoon

Key Points

- The earliest approaches to procedures in pain medicine were often hampered by the limitations of the sightless, surface landmark-driven "art of medicine." Imaging levels the playing field, as it were, by allowing all physicians to see exactly what was done.
- Image-guided options for the pain clinician included fluoroscopy, C-arm flat detector CT, ultrasound, and MRI.
- It is critical that image-guided procedures are used for proper medically indicated indications.
- New uses of imaging such as ultrasound may change the way we do current procedures. The placement of peripheral stimulation leads and the refill of difficult to access pumps are two examples of use of these emerging tools.

Introduction

The introduction of image guidance for precise targeting of anatomical structures, accurate reproduction of successful procedures, and storage of a procedural record was an important step forward for modern pain medicine. The earliest approaches to procedures in pain medicine were often hampered by the limitations of the sightless, surface landmark-driven "art of medicine." Imaging levels the playing field, as it were, by allowing all physicians to see exactly what was done. Obviously, the ability to review critical images as part of a quality management process might improve medical outcomes. However, as for many advances, there are concerns that imaging could be used by government payers, insurers, or others to restrict one's ability to participate in procedural care or receive remuneration for the procedure if the stored image does not meet specific standards [1]. Additionally, at the start of the new decade, clinicians find that technologies of the future must prove to be cost-effective. It is possible that certain technologies might improve care outcomes, but not be widely adopted by the medical community due to the fact that they do not meet a certain value threshold. Simply put if a particular image-guidance technique produces only minimal improvements by some measure (clinical outcome, decreased complication rate, etc.) but at a greater cost, the best value alternative will survive [2]. Finally, many of the procedures in interventional pain have not yet been justified by medical evidence [3]. Thus, the question of which image-guidance technique is superior (fluoroscopy, computed tomography (CT), or ultrasound (US)) for a given procedure [4] may be mute if the guided procedure is medically futile.

There are currently many barriers to adoption of image-guidance technologies. These include not only up-front equipment acquisition costs but also a significant investment in time for the requisite imaging workshops and mentored skill acquisition ("on-the-job practice time") [2].

The risks of any image-guidance technique considered for routine use are also of significance. Recent scrutiny of the risk/benefit ratio of CT scanning relative to alternative techniques has been increasingly discussed in the literature. Several publications have suggested that the rate of increase in the number of annual CT scans (now over 72 million per year) has led to detrimental effects in human health, with hard to quantitate tangible benefits [5, 6]. Cancer risk relative to dose radiation from CT has been modeled after longitudinal population-based studies of cancer occurrences in atomic bomb survivors [6]. One study suggested that, based on year 2007 CT scans, one could anticipate about 14,000 or more future cancer deaths [5]. This chapter aims to describe some of the current work going on in image guidance and imaging in general as

M.A. Huntoon, M.D.
Department of Anesthesiology,
Mayo Clinic, 200 1st Street SW, Rochester, MN 55905, USA
e-mail: huntoon.marc@mayo.edu

T.R. Deer et al. (eds.), *Comprehensive Treatment of Chronic Pain by Medical, Interventional, and Integrative Approaches*,
DOI 10.1007/978-1-4614-1560-2_55, © American Academy of Pain Medicine 2013

these topics relate to pain procedures. Specific areas where one technique may be superior to another or emerging techniques are also discussed.

C-Arm Flat Detector CT

A number of complex interventional pain procedures have emerged over the last decade, with new imaging modalities following suit. Simple target blocks such as interlaminar or transforaminal epidurals, facet procedures, and sacroiliac injections are quite easily accomplished with fluoroscopy. However, some procedures such as vertebral augmentation (vertebroplasty, kyphoplasty), celiac and hypogastric plexus neurolysis, diskography and other disk access procedures, and minimally invasive surgical procedures may be more easily accomplished with 3-dimensional fluoroscopy systems. In addition, some believe that neuromodulation procedures might be more readily accomplished with the capability to visualize in three dimensions. For example, peripheral neuromodulation procedures might be more facile with an imaging technique that showed soft tissue structures in three-dimensional or to similarly be able to detect if a spinal cord stimulation lead had migrated anteriorly. It would be an obvious advantage to avoid the hassle of bringing the conventional fluoroscopy unit back into the field and redraping it for sterility just to obtain a lateral image to verify a spinal stimulation leads location in the dorsal epidural space.

All of these modern three-dimensional systems have multifunctionality. C-arm flat detector CT (FDCT) or C-arm cone-beam CT (CBCT) may utilize different gantries but are essentially similar descriptions of these devices [7]. These systems offer what may be viewed as a "Star Wars" operating arena, where advanced optical tracking, integration of several imaging modalities (US, digital subtraction angiography, fluoroscopy, and CT) all occur in a single suite. Fluoroscopy works well to view bone structures, but in essence, there are very few procedures intended to target boney structures. Exceptions include vertebral and sacral augmentation, transpedicular fusion, etc. Yet, even in these cases where a bone target is sought, knowledge about the location and alignment of other structures such as the spinal canal, nerve roots, blood vessels, etc., is desirable to avoid complications. The limited CT scan capability of many of these systems is another plus. Instead of an image intensifier, most units have a flat detector computed tomography (FDCT) capability, which is not real time but delayed by only a few seconds. Flat panel detection enhances the accuracy and safety of the procedure as compared to plain fluoroscopy [7]. In general, interventional radiologists have been the main users of these systems, but at least two academic pain medicine practices in the United States are using equipment with these FDCT capabilities. FDCT utilizes a single rotation of the fluoroscope gantry, as opposed to conventional CT wherein there are multiple detectors and a requirement for several rotations of the gantry as the patient is moved in and out of the scanner [7]. The resulting volumetric data set from a FDCT is not as high quality as a modern 64 slice CT, but patient access is easier and more similar to conventional fluoroscopy. With FDCT, the patient stays in the same position through the imaging cycle. CT images are delayed by approximately 5–20 s. Although the images from FDCT scanning are of lower resolution, the images are most often quite adequate for the intended procedure. For example, at the author's institution, we are investigating the necessity for the traditional post-diskography CT, when compared to intraoperative FDCT images (Fig. 55.1).

Fig. 55.1 Pictured is an axial CT acquisition with FDCT demonstrating a diskogram of a structurally normal disk. Provocative testing did not yield any pain at this level

FDCT systems produce increased scatter radiation, which can result in artifacts and inaccuracies in CT calculations. Anti-scatter grids that may increase patient radiation dose are commonly used to overcome this problem. However, radiation doses are less than that for a single helical CT [7].

Cone-beam CT/FDCT units are increasingly popular for intraoperative minimally invasive surgery [8]. Transpedicular fusions are one area where this technology is being used with success. Some of the touted advantages of modern imaging system use intraoperatively are (1) reduced time for image acquisition compared to repeatedly bringing a conventional fluoroscope into the field, (2) decreased incidence of transgression of the pedicle, (3) reduced overall operating time, and (4) reduced dose of radiation to both the surgeon and the patient. For example, a recent study compared intraoperative computer-assisted spinal navigation to serial radiography for posterior fusions at the L5/S1 level. The navigation system shortened the operative time by about 40 min compared to serial radiographs [9]. More recently, a Japanese group compared isocentric three-dimensional fluoroscopy with navigation to conventional fluoroscopy for percutaneous screw placements. This large study included 300 percutaneous screw placements of which half were inserted with the advanced imaging and half with conventional fluoroscopy. They then evaluated post-procedural accuracy with 2-mm axial slice CT imaging. The authors found that there were 7.3 % exposed screws and zero perforated pedicles in the three-dimensional image group compared to 12 % exposed screws and 3.3 % perforated pedicles in the conventional fluoroscopy group. This was a statistically significant difference for pedicle screw misplacement ($P < 0.05$) [10]. In a previous study of conventional two-dimensional fluoroscopy, Weinstein et al. noted a 21 % rate of misplaced pedicle screws, with the vast majority being on the medial side (towards the spinal canal) [11]. The performance of celiac or superior hypogastric plexus neurolytic blocks is potentially impeded by the size of the local tumor burden or lymphadenopathy which may limit spread of the alcohol or phenol neurolytic solution. Other soft tissue structures such as the renal cortex, thoracic duct, abdominal aorta, or inferior vena cava for celiac plexus blocks or the iliac veins, L5/S1 disk, and L5 nerve root for superior hypogastric plexus blocks may be injured by two-dimensional guidance alone. Thus, a three-dimensional imaging system may improve block accuracy and decrease potential complications. Goldschneider et al. [12] used a 3D-RA system to perform celiac plexus blocks in children with good outcomes.

When performing vertebral augmentation procedures, it is normally considered a contraindication to proceed if a retropulsed fragment is pushing posteriorly into the spinal canal, due to the risk of neurological injury as polymethyl methacrylate (PMMA) cement is injected into the vertebral body. Knight et al. demonstrated the utility of CBCT imaging for this exact scenario, however, with a successful vertebroplasty in a patient with a retropulsed bone fragment [13]. The utilization of three-dimensional technology to better treat patients seems likely to grow as the creativity of proceduralists catches up to the capability of the imaging.

Magnetic Resonance Guidance

The use of magnetic resonance imaging (MRI) has lagged behind some of the other imaging modalities but may have significant future uses. Most physicians who treat patients with complex spine disease appreciate the superiority of the imaging of soft tissue structures with MRI. However, the lack of real-time injection, the limited access to the patient, and the need for MRI-safe equipment were significant problems to overcome. Some of the advantages of MRI imaging are the lack of radiation risks (making it potentially superior for the care of pregnant women and children as well as decreasing risks to the operator), the familiarity of spinal injectionists with MRI images, and the ability to avoid contrast dyes for patients with allergies. Disadvantages of MRI-image guidance with optical tracking include distortion of imaging with needle bending, which may malposition the graphic overlay. This may increase the number of images necessary to accurately reach the target [14]. Sequeiros and colleagues evaluated the feasibility of MR guidance with an optical tracking system for diskography. The authors found that the results were similar to those with conventional fluoroscopy or CT. A 0.23 T open configuration MRI unit was utilized. Only one complication, a collapsed disk, occurred during their study of 35 patients, with 34 procedures completed [14]. In another study, Streitparth et al. studied the outcomes of spinal injection procedures such as nerve root injection, facet joint, and sacroiliac joint injections performed in an open-field MRI of 1.0 T with vertical field orientation [15]. The authors found that proton-density-weighted turbo spin-echo (PDw TSE) technique was optimal for the image guidance. They studied 183 total injections in 53 patients. Target delivery of injectate was achieved in 100 % of the nerve root blocks, but only 87 % of the facet and sacroiliac joint injections. Posterior osteophytes limited appropriate spread in some patients. There were no major complications. MRI-image guidance has not yet come of age but may continue to grow for particular procedures. Certainly, the advantages of soft tissue imaging and lack of radiation risks warrant ongoing research.

Ultrasound

Ultrasound is another technique that has become more popular with anesthesiologists for regional block procedures and with physiatrists for musculoskeletal diagnosis and joint injections over the last decade. Some chronic pain practitioners are advocating use of ultrasound for additional procedures [2]. The ability to visualize soft tissue targets (such as nerves, blood vessels, muscles, and ligaments), evaluate for anatomic variants, and the lack of risk from radiation are attractive reasons to use US. Multiple feasibility studies have been published examining the merits of various blocks of small sensory or mixed nerves, including the ilioinguinal/iliohypogastric, saphenous, lateral femoral cutaneous, suprascapular, pudendal, intercostal, and greater occipital nerves to name a few, have turned up in the last few years [16–21]. The advantage of many of these blocks is that they had previously been targeted mostly utilizing surface landmarks. Thus, the accuracy of blockade should be increased by any of the soft tissue image-guidance techniques. Some papers have examined the use of US for axial targets, but the deeper location of these blocks, the dropout (dark hypo-acoustic window causing poor visualization) caused by bone and lack of real-time contrast injection capability, renders procedures such as epidurals, selective spinal nerve blocks, facet joint blocks, lumbar, celiac and pelvic sympathetic blocks, and a few others extremely difficult and requiring of significant experience and skill.

Sympathetic Blocks

Stellate ganglion block is an example of one sympathetic block which may be advantageous for US blockade. Kapral et al. was the first to describe this technique and noted a decrease in the number of accidental vascular punctures in an ultrasound group compared to a surface landmark group [22]. Recently summarized risks of vertebral artery or deep/ascending cervical artery uptake or neck hematoma punctuate the seriousness of complications. A review from Japan reported 27 cases of retropharyngeal hematoma after stellate ganglion block (SGB) [23]. Narouze and colleagues have described the possibility of esophageal puncture as an additional risk [24]. Celiac plexus block has been studied using an anterior approach. Injury to bowel or organs is the main risks of anterior approaches. One study that is best characterized as US-assisted celiac plexus block had good success, but by today's standards, the imaging is poor [25]. As current CT and fluoroscopy techniques are good, it is unlikely that ultrasound will make great inroads in this area.

Trigger Point and Muscular Injections

There is little glamour in the performance of deep muscular and trigger point injections, which are usually office-based procedures. Only in the thoracic area or the abdomen is there any real risk of a major complication. Fluoroscopy is basically unnecessary for these soft targets. However, ultrasound may have real advantages, as the different muscle and fascial layers can be visualized well. A deep muscle like the piriformis muscle could be targeted more accurately using US. US offers the opportunity to perform a diagnostic exam (hip rotation) to aid needle localization in the correct muscle, whereby fluoroscopy could show a contrast-striated pattern, for example, but the needle could mistakenly be in a gluteal muscle. Studies suggest excellent accuracy [26]. Trigger points in other areas have been improved by US targeting [27]. Previous closed claim data shows the danger of pneumothorax from a misplaced trigger point in the thoracic area [28].

Zygapophyseal (Facet) Joint Injections and Medial Branch Blocks

Lumbar approaches to the facet joints and the medial branch nerves have been conducted. One trial compared ultrasound-guided facet joint injections to computed tomography (CT)-guided injections [29]. Ultrasound compared favorably to the outcomes from CT in this trial. The patients with larger body mass could not be performed with US, however. Ionizing radiation doses were reduced during the study, with the US group demonstrating a mean of 14.2 ± 11.7 versus 364.4 ± 213.7 mGy.cm for the group blocked utilizing CT. The US group was also blocked in a shorter time span, which may be advantageous in a busy practice [29]. Lumbar medial branch blocks have been investigated too. One study compared blocks of the medial branches performed with US or fluoroscopy. US consistently produced blocks at the correct level suggesting precise placement, with 95 % of the needles in correct anatomical position to effectively interrupt nerve conduction [30].

A study of US utilized for third occipital nerve block procedures in the cervical spine also demonstrated good results [3] as 23 of 28 needles were placed correctly [31]. Given the fact that fluoroscopically guided procedures targeting the third occipital nerve require a three-needle approach on or around the C2/3 zygapophyseal joint, the results are intriguing.

Epidural Blocks

Epidural injections are possible with US, but due to the high reliability of fluoroscopy, it is unlikely that significant change is imminent for the performance of these techniques. Likewise, CT is unlikely to induce a significant change in physician performance for these procedures with the possible exception of cervical transforaminal procedures. All the major approaches including interlaminar, caudal, transforaminal, and selective spinal root blocks have been studied using ultrasound guidance. The one area where change may occur in the short term is for caudal injections. The sacral hiatus is identified readily with US. Caudal needles placed with US in one study of 70 patients yielded 100 % accuracy as verified by caudal epidurogram [32]. Another study examined color flow Doppler as a surrogate for contrast injection with excellent reliability of the technique in most cases [33].

Neuromodulation

Ultrasound can also be utilized to target peripheral nerves at multiple sites including the upper and lower extremities, as well as epicranial sites such as the occipital and supraorbital nerves. Two anatomical feasibility studies of peripheral nerve stimulation electrode placement next to upper and lower extremity neural targets have been conducted [34, 35]. These were followed by an initial case series of nine patients showing that the majority of patients had good long-term stimulation [36]. In one study, simulated movement of the limbs after ultrasound-guided placements demonstrated resiliency of the placement despite continuous passive motion (CPM) [35]. Occipital nerve stimulation placement is also possible with US, either directly next to the artery and nerve or in a specific fascial layer [37]. Another target for peripheral nerve stimulation is the groin, for example, the ilioinguinal nerve [38].

Combination Imaging

Very limited study has been performed to date, but there may be some scenarios where two imaging modalities at once are used for additive or synergistic effects. For cancer therapy of bone tumors, percutaneous cryoablation is often utilized. Imaging with CT to visualize the external margins of the tumor and correlation with ice-ball formation are often used. CT-fluoroscopy technique is used to pass the cryoprobe, which may also be visualized with US [39]. Other combinations of imaging modalities may be used depending on the complexity of the procedure.

Conclusion

Pain medicine procedures are challenging, and most require some form of image guidance. Increasing attention to radiation risks, physician skill levels, and procedural outcomes and safety are important future considerations. As health-care costs rise, the relative value of imaging for individual procedural performance will be paramount. Ultrasound will have some utility, particularly for nerve, joint, and superficial targets. As the move to minimally invasive surgery takes hold, advanced FDCT systems may also be utilized with increasing frequency. But in the final analysis, best practice may continue to favor fluoroscopy for some procedures. It will likely fall to comparative outcomes researchers to answer the questions of which imaging is appropriate for a select procedure in the future.

References

1. American College of Occupational and Environmental Medicine. Chap. 12: Low back disorders. In: Occupational medicine practice guidelines. 2nd ed. Elk Grove Village: American College of Occupational and Environmental Medicine; 2008.
2. Huntoon MA. Ultrasound in pain medicine: advanced weaponry or just a fad? Reg Anesth. 2009;34:387–8.
3. Manchikanti L, Boswell MV, Singh V, et al. Comprehensive evidence-based guidelines for interventional techniques in the management of chronic spinal pain. Pain Physician. 2009;12:699–802.
4. el-Khoury GY, Ehara S, Weinstein JN, Montgomery WJ, Kathol MH. Epidural steroid injection: a procedure ideally performed with fluoroscopic control. Radiology. 1988;168:554–7.
5. Berrington de Gonzalez A, Mahesh M, Kim K-P, Bhargavan M, Lewis R, Mettler F, Land C. Projected cancer risks from computed tomographic scans performed in the United States in 2007. Arch Intern Med. 2009;169:2071–7.
6. Brenner DJ, Hall EJ. Computed tomography – an increasing source of radiation exposure. N Engl J Med. 2007;357:2277–84.
7. Orth RC, Wallace MJ, Kuo MD. C-arm cone-beam CT: general principles and technical considerations for use in interventional radiology. J Vasc Interv Radiol. 2008;19:814–21.
8. Siewerdsen JH, Moseley DJ, Burch S, et al. Volume CT with flat-panel detector on a mobile, isocentric C-arm: pre-clinical investigation in guidance of minimally invasive surgery. Med Phys. 2005;32:241–54.
9. Sasso RC, Garrido BJ. Computer-assisted spinal navigation versus serial radiography for posterior spinal fusion at L5/S1. J Spinal Disord Tech. 2007;20:118–22. http://www.ncbi.nlm.nih.gov/pubmed/17414979
10. Nakashima H, Sato K, Ando T, Inoh H, Nakamura H. Comparison of the percutaneous screw placement precision of isocentric C-arm 3-dimensional fluoroscopy-navigated pedicle screw implantation and conventional fluoroscopy method with minimally invasive surgery. J Spinal Disord Tech. 2009;22:468–72.
11. Weinstein JN, Spratt KF, Spengler D, et al. Spinal pedicle fixation: reliability and validity of roentgenogram-based assessment and surgical factors on successful screw placement. Spine. 1988;13:1012–8.
12. Goldschneider KR, Racadio JM, Weidner NJ. Celiac plexus blockade in children using a three-dimensional fluoroscopic reconstruction technique: case reports. Reg Anesth Pain Med. 2007;32:510–5.
13. Knight JR, Heran M, Munk PL, Raabe R, Liu DM. C-arm cone-beam CT: applications for spinal cement augmentation demonstrated by three cases. J Vasc Interv Radiol. 2008;19:1118–22.
14. Sequeiros RB, Klemola R, Ojala R, et al. Percutaneous MR-guided discography in a low-field system using optical instrument tracking: a feasibility study. J Magn Reson Imaging. 2003;17:214–9.
15. Streitparth F, Walter T, Wonneberger U, et al. Image-guided spinal injection procedures in open high-field MRI with vertical field orientation: feasibility and technical features. Eur Radiol. 2010;20:395–403.
16. Eichenberger U, Greher M, Kirchmair L, et al. Ultrasound – guided blocks of the ilioinguinal and iliohypogastric nerve: accuracy of a selective new technique confirmed by anatomical dissection. Br J Anaesth. 2006;97:238–43.
17. Gofeld M, Christakis M. Sonographically guided ilioinguinal nerve block. J Ultrasound Med. 2006;25:1571–5.
18. Rofaeel A, Peng P, Louis I, Chan V. Feasibility of real-time ultrasound for pudendal nerve block in patients with chronic perineal pain. Reg Anesth Pain Med. 2008;33:139–45.
19. Peng P, Narouze S. Ultrasound-guided interventional procedures in pain medicine. Part 1: non axial structures. Reg Anesth Pain Med. 2009;34:458–74.
20. Byas-Smith MG, Gulati A. Ultrasound-guided intercostal nerve cryoablation. Anesth Analg. 2006;103:1033–5.
21. Harmon D, Hearty C. Ultrasound guided suprascapular nerve block technique. Pain Physician. 2007;10:743–6.
22. Kapral S, Krafft P, Gosch M, Fleischmann M, Weinstabl C. Ultrasound imaging for stellate ganglion block: direct visualization of puncture site and local anesthetic spread. A pilot study. Reg Anesth. 1995;20:323–8.
23. Higa K, Hirata K, Hirota K, Nitahara K, Shono S. Retropharyngeal hematoma after stellate ganglion block. Anesthesiology. 2006;105:1238–45.
24. Narouze S, Vydyanathan A, Patel N. Ultrasound-guided stellate ganglion block successfully prevented esophageal puncture. Pain Physician. 2007;10:747–52.
25. Montero Matamala A, Vidal Lopez F, Aguilar Sanchez JL, Bach LD. Percutaneous anterior approach to the coeliac plexus using ultrasound. Br J Anaesth. 1989;62:637–40.

26. Smith J, Hurdle M-F, Locketz AJ, Wisnewski SJ. Ultrasound-guided piriformis injection: technique description and verification. Arch Phys Med Rehabil. 2006;87:1664–7.
27. Botwin KP, Sharma K, Saliba R, Patel BC. Ultrasound-guided trigger point injections in the cervicothoracic musculature: a new and unreported technique. Pain Physician. 2008;11:885–9.
28. Fitzgibbon DR, Posner KL, Domino KB, et al. Chronic pain management: ASA Closed Claims Project. Anesthesiology. 2004;100: 98–105.
29. Galiano K, Obwegeser AA, Walch C, et al. Ultrasound – guided versus computed tomography- controlled facet joint injections in the lumbar spine: a prospective randomized clinical trial. Reg Anesth Pain Med. 2007;32:317–22.
30. Shim JK, Moon JC, Yoon KB, Kim WO, Yoon DM. Ultrasound-guided lumbar medial- branch block: a clinical study with fluoroscopy control. Reg Anesth Pain Med. 2006;31:451–4.
31. Eichenberger U, Greher M, Kapral S, et al. Sonographic visualization and ultrasound-guided block of the third occipital nerve: prospective for a new method to diagnose C2/3 zygapophysial joint pain. Anesthesiology. 2006;104:303–8.
32. Chen CP, Tang SF, Hsu TC, Tsai WC, Liu HP, Chen MJ, Date E, Lew HL. Ultrasound guidance in caudal epidural needle placement. Anesthesiology. 2004;101:181–4.
33. Yoon JS, Sim KH, Kim SJ, et al. The feasibility of color Doppler ultrasonography for caudal epidural steroid injection. Pain. 2005;118:210–4.
34. Huntoon MA, Huntoon EA, Obray JB, Lamer TJ. Feasibility of ultrasound guided percutaneous placement of peripheral nerve stimulation electrodes in a cadaver model: part one, lower extremity. Reg Anesth Pain Med. 2008;33(6):551–7.
35. Huntoon MA, Hoelzer BC, Burgher AH, Hurdle MF, Huntoon EA. Feasibility of ultrasound-guided percutaneous placement of peripheral nerve stimulation electrodes and anchoring during simulated movement: part two, upper extremity. Reg Anesth Pain Med. 2008;33(6):558–65.
36. Huntoon MA, Burgher AH. Ultrasound-guided permanent implantation of peripheral nerve stimulation (PNS) system for neuropathic pain of the extremities: original cases and outcomes. Pain Med. 2009;10:1369–77.
37. Hayek SM, Jasper JF, Deer TR, Narouze SN. Occipital neurostimulation-induced muscle spasms: implications for lead placement. Pain Physician. 2009;12:867–76.
38. Carayannopouos A, Beasley R, Sites B. Facilitation of percutaneous trial lead placement with ultrasound guidance for peripheral nerve stimulation trial of ilioinguinal neuralgia: a technical note. Neuromodulation. 2009;12:296–301.
39. Callstrom MR, Atwell TD, Charboneau JW, et al. Painful metastasis involving bone: percutaneous image-guided cryoablation-prospective trial interim analysis. Radiology. 2006;241:572–80.