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Interventional Pain Management using Fluoroscopy and Ultrasound Imaging Techniques

Irina Evansa*/**, Edgars Vasilevskis*, Michail Aron**, Inara Logina***, Indulis Vanags******
*Hospital of Orthopaedic Surgery, Riga, Latvia
**Riga 1 st Emergency Care Hospital, Anaesthesiology and Intensive Care Department, Latvia
***Riga Stradins University, Department of Neurology and Neurosurgery, Latvia
****Riga Stradins University, Department of Anaesthesiology and Reanimatology, Latvia
***** Riga Stradins University, Department of Doctoral studies, Riga, Latvia

Summary
Interventional injection therapies play a major role in the management of various pain conditions and are becoming an integral part of the multidisciplinary therapies required to improve and rehabilitate pain patients. Many of these procedures have historically been performed without imaging guidance. Imaging–guided techniques with fluoroscopy or ultrasound increase the precision of these procedures and help confirm needle placement. Imaging–guided techniques should lead to better results and reduced complication rates and they are now becoming more popular. These improvements are probably due in part also to better patient selection by experienced pain physicians.
Key words: pain management, spinal interventions, imaging techniques, fluoroscopy, ultrasound, visualization.

INTRODUCTION

Interventional Pain Management is the discipline of medicine devoted to the diagnosis and treatment of pain related disorders with the application of interventional techniques in managing sub acute, chronic, persistent, and intractable pain, independently or in conjunction with other modalities of treatment.

For back pain sufferers, interventional pain management techniques can be particularly useful. In addition to a thorough medical history and physical examination, interventional pain management physicians have a wide array of treatments that can be used including the following: (2)

- Epidural injections (in all areas of the spine): the use of anesthetic and steroid medications injected into the epidural space to relieve pain or diagnose a specific condition.
- Nerve, root, and medial branch blocks: injections administered to determine if a specific spinal nerve root is the source of pain. Blocks also can be used to reduce inflammation and pain.
- Facet joint injections: an injection used to determine if the facet joints are the source of pain. These injections can also provide pain relief.
- Discography: an "inside" look into the discs to determine if they are the source of a patient's pain. This procedure involves the use of a dye that is injected into a disc and then examined using X–ray or computed tomography.
- Pulsed radiofrequency neurotomy: a minimally invasive procedure that disables spinal nerves and prevents them from transmitting pain signals to the brain.
- Rhizotomy: a procedure in which pain signals are "turned off" through the use of heated electrodes that are applied to specific nerves that carry pain signals to the brain.
- Spinal cord stimulation: the use of electrical impulses that are used to block pain from being perceived in the brain.
- Intrathecal pumps: a surgically implanted pump that delivers pain medications to the precise location in the spine where the pain is located.
- Percutaneous Discectomy/Nucleoplasty: a procedure in which tissue is removed from the disc in order to decompress and relieve pressure.

Many pain procedures can not be performed with a blind technique, or at cost of high failure rate and unacceptable risks. Imaging–guided techniques with fluoroscopy or computed tomography increase the precision of these procedures and help confirm needle placement. Cervical, thoracic, lumbosacral, and sacroiliac pain can be evaluated and treated safely and effectively with injections of local anesthetics or long–acting steroids into facet joints, sacroiliac joints, selective nerve roots, spondylolytic areas, and the epidural space. Because imaging–guided techniques appear to provide better results and reduce complication rates, they are becoming more popular despite controversy regarding their effectiveness.

Fluoroscopic guided spinal interventions

The use of fluoroscopy has revolutionized interventional pain management. Fluoroscopy is required in difficult procedures where precise needle placement is required. Fluoroscopy is a radiology technique that takes a real time "movie" of the body. A continuous x–ray beam is

passed through the body part being examined, and is transmitted to a TV–like monitor so that the body part and its motion can be seen in detail.

Fluoroscopy is used so the doctors are able to administer any injections under x–ray guidance. Fluoroscopy equipment allowing to carry out minor procedures and treatment. The fluoroscopic guided spinal injections include:

- Facet Injections
- Nerve root blocks
- Sacroiliac injections
- Epidural injections

Anatomical landmarks can be difficult to recognize especially in obese, elderly, or arthritic patients (16) with spinal stenosis. Narrowing of the lumbar spinal canal is an increasingly common problem, affecting 1 person per 1000 persons older than 65 years (11). Spinal stenos is a degenerative condition, part of the aging process. Patients generally become symptomatic at age 50 years or older. It is estimated that 5 out of every 1000 Americans older than 50 years have symptoms of spinal stenosis (4). The degeneration of the motion segment vertebral column – the intervertebral disk and the facet joints – is believed to be the pathophysiologic mechanism involved with the development of stenosis. Degenerative changes in the spine including osteophyte formation, facet hypertrophy, bulging disks, and hypertrophy of the ligamentum flavum can result in canal or foraminal narrowing. Spondylolisthesis (the displacement of one vertebra on top of another) can further compromise the canal. . In the treatment of these patients the needle may be inadvertently placed intradurally or intravascularly or may not even be in the canal.

Several studies on epidural steroid injections showed the usefulness of fluoroscopy. In clinical practice, the most commonly used technique for identifying the epidural space is the loss of resistance to air or saline technique. Previous reports (23) have suggested that the LOR technique (without fluoroscopic guidance) may be inadequate for identifying the lumbar epidural space. There has also been a report on a high incidence of discontinuity in the ligamentum flavum in the cervical region (7). The use of fluoroscopy can diminish these risks. Fluoroscopic guidance is recommended for all epidural injections. Injection of non–ionic contrast material to confirm the needle position is also recommended. Machikanti (15) emphasized the necessity of using fluoroscopy in epidural steroid injections. The low incidence of the dye reaching the level of pathology requires the use of fluoroscopy to eliminate the question of incorrect needle placement with blind injections. The difficulty in placing the epidural needle may be due to fibrosis and adhesions within the epidural space making the loss of resistance sign equivocal.

One of the earlier studies on epidural steroid injections showed that blind placements were accurate in 83 of 100 patients (16). In this study where 85% of the injections were performed in the lumbar area, experienced anesthesiologists performed the interlaminar epidural placement yet the incidence of inaccurate placement was 17%. Another study where the epidurals were placed by experienced anesthesiologists and an orthopedic surgeon showed a 75% success rate with blind epidural placement (23).

Epidural injection of steroids has become an accepted treatment for low back pain (10). This procedure is performed by a number of specialists involved in pain management, including anesthesiologists, radiologists, and physiatrists (5, 19). Correct placement of the steroid solution is obviously important for this technique, and there is controversy over the need for fluoroscopy to guide correct epidural placement (19). Patients treated in pain management clinics for low back pain often have altered epidural anatomy with changes in resistance characteristics of the epidural space (21). Epidural steroid injection is a safe outpatient procedure, which is performed by best using image guidance in conjunction with epidurography. Using the techniques described earlier, complications are minimized, and serious complications can be avoided, in experienced hands. The author has performed hundred of procedures in an outpatient setting without any serious complications. Optimal safety and efficacy require an excellent working knowledge of the radiographic anatomy, and the imaging equipment used to perform these procedures. Several studies have demonstrated the difficulty and uncertainty of obtaining an accurate injection without imaging guidance. Therefore, fluoroscopic control using contrast confirmation of needle placement is mandatory to ensure safe and effective needle placement (3, 8, and 21).

Tripathi et al., report (22) describing a case of paraplegia in an awake patient who underwent a spinal injection procedure with the use of fluoroscopy contains the remark, "it seems fluoroscopy guidance may not prevent intrathecal perforation or spinal cord penetration." This report points out yet another example of how using fluoroscopy does not protect patients from injection–related complications.

Of note, a recent report published in the APSF Newsletter (14), reviewing closed–claims data, analyzed 13 anesthesiology claims related to alleged complications after cervical epidural steroid injections. Twelve of these 13 cases involved the use of fluoroscopy. Whereas fluoroscopy, computed tomography, magnetic resonance imaging, and, more recently, ultrasound have been used for needle localization for spinal injection procedures, it is important to remember that imaging alone cannot guarantee against potential complications. In fact, radiographic guidance for injection procedures may provide a false sense of safety and, without proper training of the operator, and may lead to worse patient safety outcomes (9, 14, and 22). Fluoroscopic guidance for spinal procedures may offer precision for needle placement but it does not provide improved patient safety if the operator is not properly trained. In reality,

even under fluoroscopic guidance, imprecise needle placement at an unintended spinal level or performance of an altogether different procedure has been reported (19). The American Board of Medical Specialties, insurance providers, and policy makers should consider limiting the performance of interventional pain procedures to physicians who have trained in Accreditation Council for Graduate Medical Education–accredited pain medicine fellowship programs. It is our belief that allowing only pain medicine fellowship–trained physicians to perform spinal injection therapies will result in improved safety for this group of patients (4).

Ultrasound–guided spinal interventions

Ultrasound is an increasingly used imaging technique in interventional pain management. It allows the identification of soft tissues, vessels and nerves, without exposing patients and personnel to radiation. Imaging can be performed continuously and the fluid injected is visualized in a real time fashion. Possible applications are nerve blocks of the cervical and lumbar facet joints, stellate ganglion block, intercostal nerve blocks, and blocks of painful stump neuromas, caudal epidural injections and injections of trigger/tender points (12). Due to direct nerve visualization, ultrasound has a potential application for destructive procedures, such as cryoanalgesia, radiofrequency lesions or chemical neurolysis. Limitations are, the poor resolution of narrow–gauge needles, the lost of resolution with an increasing working depth and possible interference of echoes from overlying structures within the image of the target area (18). Ultrasound open new perspectives in interventional pain management. However, there is a need for clinical trials investigating efficacy and safety of ultrasound guided pain procedures. Until these studies are completed, ultrasound cannot replace fluoroscopy or computed tomography in routine clinical practice and remains domain of well–trained and experienced physicians. The limited evidence supporting the clinical utility of nerve blocks remains a problem, irrespective of the imaging techniques employed.

Although ultrasound has proven useful in regional and labor related anesthesia, no studies of epidural steroid injection under ultrasound guidance have appeared in the literature (1). In fact, this application should be discouraged, because the technical ability to identify the correct level for injection does not necessarily imply proper deposition of injection into the ventral epidural space and/or adjacent to the dorsal root ganglion. Because the energy of sound is completely absorbed by bone tissue, the injected solution cannot be seen within the epidural space. One might argue that, compared with "blind" injection, ultrasound at least offers accurate localization of the epidural space; nevertheless, it seems imprudent to recommend an incorrect approach merely because it is less harmful than an incorrect approach that is known to be harmful (18) .

Two clinical studies (13, 24) have reported the usefulness of ultrasound imaging in caudal injections of corticosteroid. One of them even described Doppler ultrasound as a tool for verifying deposition of injection into the sacral canal. Notwithstanding the success of proper needle positioning, this method has the same flaws as other ultrasound assisted neuroaxial injections the inability to track the spread of the injected solution beyond the injection site. Therefore, this technique can be recommended only for remote facilities without access to a radiology suite. Its main advantage is in the confirmation of correct needle placement.

Nonetheless, the technique may be an attractive alternative to fluoroscopy if the patient is allergic to iodine or fluoroscopy is unavailable. In this case, a water–soluble corticosteroid (specifically, dexamethasone) must be used (2).

The application of ultrasound in chronic pain management remains in an embryonic state and number of reasons can be suggested to explain this situation. First, image quality was poor, which makes interpretation extremely difficult. Second, because of the technical requirements, relatively few experts have had the skills needed to use this tool, although recent improvements in resolution and processing have made it possible for most operators to distinguish small anatomic parts, including nerves. Third, diagnostic soft–tissue ultrasound has been generally abandoned in favor of magnetic resonance imaging. Obviously, the latter has greater capability for soft–tissue imaging, but performing injections under magnetic resonance imaging guidance requires time, special equipment, and expertise in interventional rather than diagnostic radiology; it would also be exceptionally and unjustifiably expensive. Therefore, magnetic resonance imaging will never rival ultrasound in routine clinical practice. Fourth, there is a deeply rooted acceptance of fluoroscopy and computed tomography as the gold standards of imaging in pain medicine. As such, pain societies and their members promote education and expertise in these methods (particularly fluoroscopy), but it could be that their knowledge of ultrasound is simply too limited to recognize its value. Fifth, advanced pain practitioners are still struggling to convince the wider medical community, as well as payers (medical insurance) and patients, that only image–guided procedures should be performed and that the custom of office–based "nerve blockade" should be discouraged. Sixth, the quality control of ultrasound guided injections is questionable, and there is a constant danger of "technological hijacking" whereby invalidated and potentially harmful injections of all types are folded into the curricula for "image–guided procedures" (6). Ultrasound allows visualization of soft tissues, vessels, and nerves. In contrast to fluoroscopy, it does not require X–ray compatible suite and protective gear, and there are no overhead costs for maintenance of equipment. Patients and medical personnel are not exposed to radiation, and the waiting time for a procedure can be significantly reduced. This technology does have limitations. Ultrasound offers only a narrow imaging

window, which is extremely sensitive to the probe's position and direction (1). Tissue artifacts may lead to interpretation errors, whereby other tissues, such as tendon, vessel, connective tissue, or lymph nodes, are interpreted as nerves. Therefore, in–depth knowledge of applied anatomy and specific training is required to master these techniques. US cannot penetrate bone and therefore should not be used when the target is obscured by bone tissue (24). Finally, anatomic abnormalities such as obesity or severe degenerative changes condition may diminish the effectiveness of ultrasound.

CONCLUSIONS

Clinical trials are needed to investigate the efficacy and safety of ultrasound guided pain procedures. Until firm evidence is available, ultrasound cannot replace radiology–based methods in routine clinical practice, especially for neuroaxial injections. Fluoroscopy and computed tomography should remain the standard image guidance tools for patients whose anatomic features pose particular challenges (e.g., obesity, severe degenerative changes, malformation); ultrasound can be implemented in the office–based practice for diagnostic and therapeutic injections. Using ultrasound for diagnostic comparative nerve blocks may have additional value in terms of the timing of the diagnosis and treatment. Because this procedure does not require a special setting (e.g., imaging suite) or additional personnel, and it can be performed at the time of initial assessment. If the result is positive, the confirmatory injection can be scheduled for a subsequent date and the physician may choose ultrasound or fluoroscopy guidance to exclude a false or positive response.

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Address:
Irina Evansa
Hospital of Orthopaedic Surgery,
Gimnastikas Street 1, Riga, LV-1004, Latvia
E-mail: irina.evansa@inbox.lv