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REVIEW

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Interventional non-operative management of low back and neck pain

Hazem M. Alkosha*

Abstract

Background Chronic neck and back pain are among the most commonly encountered health problems in neurosurgical practice. Many cases fail prolonged pharmacological and physical therapy and are not proper candidates for surgical interventions, or had refused proposed surgical treatment.

Objective To provide an informative critical summary of the literature about the topic of interventional management of axial neck and low back pain and highlighting the new trends and pieces of evidence.

Methods The English literature published over the last two decades was reviewed by the author for recent and relevant data about the principles of interventional management of chronic neck and low back pain. A PubMed search was performed through phrase searching and combined searching using Boolean operators. The articles thought to be most relevant to the study aim and the neurosurgeons' practice were extracted.

Results Neck and low back pain continue to be among the most common musculoskeletal health problems and the most common cause of disability worldwide. A detailed understanding of relevant spine anatomy is crucial for interventionists who should deal with the concept of "functional spine unit" with multiple potential pain generators. Chronic spinal pain is best managed through a dedicated multidisciplinary team in well-equipped healthcare facilities. An algorithmic approach for the diagnosis and management of spinal pain is the mainstay of providing the best patient care and should be based on the commonality and treatability of pain generators, values of patients and available resources.

Conclusion Management of chronic neck and back pain can represent a clinical dilemma due to the multiplicity of pain generators that may coexist in the same individual resulting in a complex type and pattern of pain. Approach to these patients requires contributions from the members of a multidisciplinary team, implementing a standardized approach in a well-equipped healthcare facility.

Keywords Interventional, Neck pain, Low back pain, Injection therapy, Percutaneous, Radiofrequency, Multidisciplinary

Introduction

Generally, neck and back pain are routinely classified among the top 5 disabling health problems in the USA [1]. The great majority of neck and low back pain complaints are distinguished in the literature as having non-specific nature and self-limiting courses, but with high recurrence rates [2, 3]. The duration of the first painful episode, particularly low back pain, has a positive association with the likelihood of recurrence, with each recurrence characterized by increasing disability and severity [4, 5]. This indicates that what occurs during the first painful episode may have a significant impact on the instance and severity of succeeding episodes and the evolution of long-term disability.

*Correspondence:
Hazem M. Alkosha
hazem_kosha@yahoo.com
Department of Neurosurgery, Mansoura University, Al Gomhurrya Street, Mansoura, Egypt

Interventional modalities for neck and low back pain have emerged as promising and effective management tools for spinal painful episodes in view of their non-specific nature and influence on recurrence and quality of life. The rising healthcare utilization has resulted in a significantly rising healthcare cost [6]. These modalities are effective when combined with other adjuvant modalities and executed by well-trained physicians who are knowledgeable in the anatomy and physiology of chronic pain and skilled in the techniques of such delicate procedures. Failure of responding to a low back or neck pain interventional modality can have a multifactorial underlying aetiology. Improper patient selection, patient noncompliance or non-adherence and poorly performed technique may all be underlying causes of failure. The American College of Occupational and Environmental Medicine and the American Society of Interventional Pain Physicians have developed guidelines to ensure following the standard of care in selecting the appropriate interventional technique for indicated medical conditions [7–9].

Methods

The English literature over the last two decades discussing relevant topics was thoroughly reviewed. The PubMed database was last searched by the author for the articles related to interventional management of neck and low back pain on 6 August 2022. The search process is composed of primary and secondary searches. The primary search included both phrase searching and combined searches using the Boolean operators. Phrase searching was done using the following phrases: "interventional management", "chronic neck pain" and "chronic low back pain". Using Advanced Search, Boolean Search box was used to search the following: [interventional] AND [pain], [injection] AND [pain], [radiofrequency] AND [pain], [percutaneous] AND [pain] & [multidisciplinary] AND [pain]. Secondary research was done in a delayed fashion during scientific writing for further complementary studies. The author used Boolean search again such as: [interventional] AND [equipment], [algorithmic] AND [pain], [interventional] AND [evidence] & [generators] AND [pain]. The selection process of articles was a subjective process, based on the landmark studies and literature reviews that are relevant to the aim of the study from the author's point of view.

Epidemiology of back and neck pain

Low back pain and neck pain are commonly encountered health problems during routine neurosurgical practice and run episodic courses over an individual's lifetime [10, 11]. Low back pain is considered the most common type of musculoskeletal health problems worldwide and is the leading cause of activity confinement and employee absenteeism, representing a major medical burden and one of the greatest global public health issues [12–15]. Similarly, neck pain is a common health problem causing considerable disability with a rising prevalence in both general and specific occupational groups [16]. The mean overall prevalence of neck pain was estimated to be 23.1% of the general population, with 1-year prevalence ranging from 4.8 to 79.5% [17]. Based on the Global Burden of Disease 2016 study, spinal pain (including low back and neck pain) was found to be the most common cause of disability in the region of North America and worldwide for people aged 25–64 years [18].

Relevant anatomy

Variation in the number of vertebrae may occur as a result of L5 sacralization, S1 lumbarization, absence of a rib at the lowest thoracic level (apparent extra lumbar vertebra) and presence of thoracic costal facets at C7 vertebra (apparent extra thoracic vertebra) [19]. Reliable vertebral level numbering is of utmost importance during interventional procedures for accurate diagnosis and treatment guidance. Summation of the small movements of the individual spinal units produces a potentially large degree of spinal movements including flexion, extension, lateral bending, and axial rotation [20].

Each IVD is composed of a central nucleus pulposus, a ring of annulus fibrosis and 2 cartilaginous endplates separating the disc from the bony vertebrae [21, 22]. The IVD is innervated by branches from the sinuvertebral nerve (nerve of Luschka) which carry sensory nerve fibres from the ventral rami of spinal nerves and sympathetic fibres from the grey rami communicants. The sensory nerve fibres are mainly nociceptive and to a lesser extent proprioceptive in nature and usually infiltrate the external lamellae of annulus fibrosus [23]. The facet joints are dually innervated receiving paired medial branches of the dorsal rami of the spinal nerves at the same level and the level above. The exceptions for this dual nerve supply are the atlanto-occipital, atlantoaxial, and C2/3 facet joint, supplied by C1, C2 and C3 spinal nerves, respectively [24]. Sacroiliac joint (SIJ) is a diarthrodial joint surrounded by a fibrous capsule and filled with synovial fluid [25]. The stability of this joint is provided primarily through a rich ligamentous network holding the articular surfaces and to a lesser extent through the articular surfaces morphology, with contributions from the attached myofascial structures [26]. The joint receives nerve supply from the ventral rami of L4 and L5, superior gluteal nerve, and the dorsal rami of L5-S2 [27].

Several bony structures are of particular importance during interventional procedures; the dens, the atlanto-axial joints, the ring apophyses, the pedicles, the spinous processes and the pars interarticularis (Fig. 1). The dens

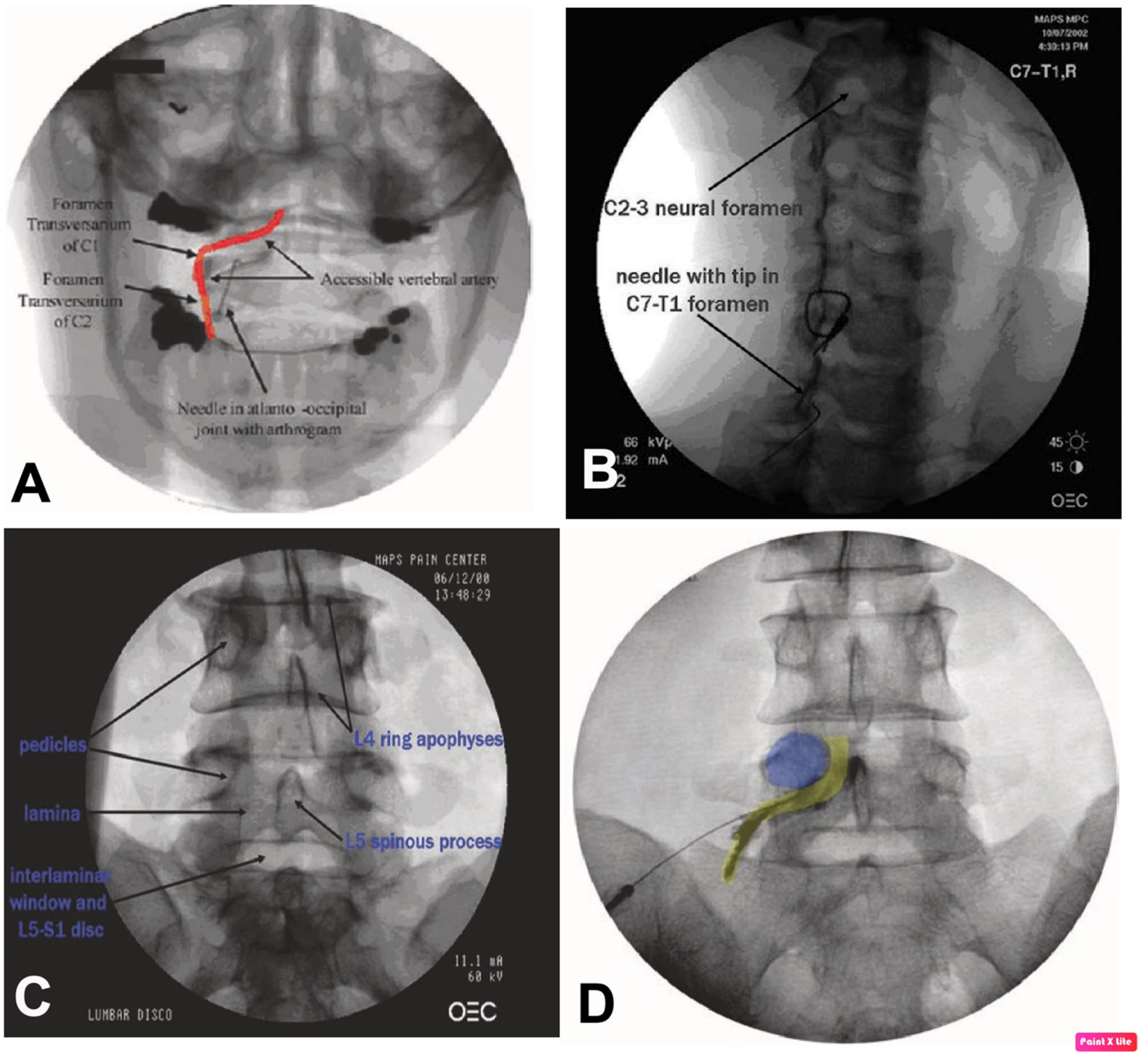

Fig. 1 Fluoroscopic images showing; **A** the location of vertebral artery passing lateral to the atlantoaxial joint and the dense centralized between both atlantoaxial joints in "open-mouth view". The needle can be seen inside the atlantoaxial joint. **B** oblique lateral view of the cervical spine showing the pedicles of vertebrae and C2-3 through C7-T1 neural foramina with the tip of the needle at the posterior aspect of C7-T1 foramen dorsal to C8 nerve root. **C** Antero-posterior view of lumbar spine with ring apophyses of L5 squared up to obtained a true AP view. The spinous process is centralized between both pedicles which appear as two rounded hyper dense areas at superior aspect of L5 vertebra bilaterally. **D** The relation of the exiting nerve root to the corresponding pedicle. The tip of the needle can be seen inferior to the pedicle for transforaminal injection. (Constructed from [20])

can be easily visualized via AP open-mouth view and can be used in high spinal procedures as a guide to position the fluoroscope in a true AP plane and identify nearby structures. The atlantoaxial joints are hallmarks for the vertebral arteries which are consistently lateral to the joints as they course through the foramina transversaria of C1 and C2. The ring apophyses are circumferential rings of compact bone surrounding the roof and floor of the vertebral body and are seen on fluoroscopy as rings of increased density that identify vertebral endplates. They are used for "squaring up" the fluoroscope with each spinal segment by inclining the C-arm in a craniocaudal fashion to avoid tilted images. The pedicles are crucial landmarks for needle placement since they are closely associated with spinal nerve roots that exit just beneath the numerically equivalent pedicles in the thoracolumbar spine. The spinous processes help identification of the midline in AP fluoroscopic projections. The pars interarticularis which is the thick portion of lamina connecting the superior and inferior articular processes of a single vertebra on one side can be the site of stress fracture disconnecting the posterior arch from an anterior column and constituting a "flail segment". Injection of local anaesthetics into the pars defect can help to decide whether or not it is implicated in pain generation, as Bogduk reported previously that pars defects are not usually painful and can be detected in 10% of asymptomatic individuals [20, 28].

Pain generators and the concept of functional spine unit

Common causes of neck and back pain include pars defects, discogenic, facet-mediated, myofascial, ligamentous and nerve sheath-related pain [29, 30]. Among the various factors generating axial pain, IVDs, FJs and SIJ are involved in 45, 40 and 13%, respectively [31]. The traditional treatment of cases refractory to pharmacological and physical therapy includes corticosteroid injections targeted to these specific structures, radiofrequency ablation and surgery in severe debilitating cases [32, 33].

Disc degeneration is induced by progressive disc dehydration as a consequence of a reduction in the synthesis of the proteoglycan matrix. The cell concentration progressively declines, particularly in the annulus fibrosus. Repeated injury results in the production of tumour necrosis factor and interleukin-1 accelerating the loss of proteoglycans with a decline in matrix turnover [34]. It has been reported that in degenerating IVDs, particularly in painful IVDs, innervation is increased with the ingrowth of the nociceptive fibres into the aneural inner parts of the annulus and even into the nucleus pulposus, sometimes together with blood vessels [35]. Facet joint degenerative osteoarthritis (OA) is the most common form of facet joint-mediated pain and is closely linked to the degeneration of IVDs [35]. It is a continuum between joint space narrowing, synovial fluid loss, cartilage necrosis and bone overgrowth. Facet joint degeneration can generate inflammation of the joint and the surrounding tissue resulting in local pain [35]. In a cadaveric study, facet joint OA was detected in more than 50% of adults younger than 30 years and 100% of adults older than 60 years [36]. Degenerative spondylolisthesis is related in the majority of cases to facet OA causing progressive cartilage loss, articular remodelling and eventually segmental instability and capsule tension [37]. Septic and inflammatory arthritis as well as, ankylosing spondylitis can also be less common causes of facet-mediated axial pain [35]. Sacroiliac joint pain is also a frequent focus of axial pain, although being less common than IVDs and FJs. Arthritis and spondyloarthropathies are the two most common intra-articular causes of SIJ pain, while muscular and ligamentous injuries, as well as enthesopathy, are likely the most frequent extra-articular aetiologies [38].

The last two decades had witnessed a utilization increase in interventional therapy for neck and back pain [6, 32], despite the disappointing results based on cost and efficacy, and the lack of evidence of long-term relief from facet joint blocks even with repeated injections [6, 32, 39, 40]. Moreover, recent studies proposed that the analgesics and steroids commonly utilized in these injections may play a role in the progression of arthritis [41–43]. Although some evidence exists that neurolysis procedures can produce longer-term relief, this could contribute to deep segmental stabilizer denervation and muscle atrophy [6, 44]. Only limited success of surgery has been demonstrated for the treatment of back and neck pain without severe neurological deficit, while carrying a much higher risk than percutaneous injections [45].

The relatively limited efficacy of the traditional approaches in face of the increasing burden of musculoskeletal disorders has spurred an intense interest in alternative treatments modalities, like regenerative injection treatment (RIT) which includes injections of proliferative solutions, cells or growth factors, aiming to repair or strengthen injured or weak structures [46]. Parallel to this is the expansion of the traditional philosophy for interventional pain management beyond the "single pain generator" model to include the entire osteoligamentous complex, with the emergence of the concept of the "functional spinal unit" (FSU) model [47]. Following this model, multiple tissue types related to the spine are to be targeted and treated, including IVDs, synovial joints, muscles, fascia and ligaments.

Multidisciplinary team and approach to spinal pain management

Low back and neck pain, especially chronic pain can be an extremely complex health issue and requires input from a number of multiple specialties in order to properly diagnose patients and effectively provide treatments. Accordingly, low back and neck pain are properly approached and managed through a multidisciplinary team (MDT). The benefit of MDT in managing patients with chronic pain has been consistently demonstrated, not only in terms of pain reduction, but also regarding physical functioning, psychological improvement and quality of life [48, 49]. However, the full and proper function of this MDT requires setting and implementing a clear policy that ensures full integration and cooperation of team members, as well as a clear designation of responsibilities and identification of liability, should a complication or malpractice subsequently lead to litigation.

There is no consensus on a specific composition of an MDT; however, a typical team should include practitioners from different medical disciplines. The incorporation of a wide range of specialties maximizes patients' benefits from the incorporation of several areas of expertise and the various treatments they offer. Moreover, the MDT will be better placed to evaluate and treat the multiple physical, social and psychological aspects of chronic pain [50]. Therefore, the core members of an MDT usually include practitioners from 3 or more of the following specialties:

- A spine surgeon whether from a neurosurgical or an orthopaedic background. Surgical intervention may be indicated for some cases, while an option for others. Functional assessment and the need for surgical interventions is usually the responsibility of spine surgeons [50].
- Pain Medicine Physicians. They can carry out interventional procedures and are vitally incorporated in the pharmacological provision for adequate pain control, resulting in improvements in the lifestyle including mood, sleep and exercise tolerance [50, 51]. Most pain physicians come from a background in anaesthesia, with an additional training in managing different types of pain [52]. Moreover, dealing with a subjective experience like pain that lacks for confirmatory tests [52, 53], puts a wide differential diagnosis that may explain patient's manifestations [54, 55].
- A neurologist. Neurologists are likely to be involved in the MDT for treating non-cancer spinal pain, as pain management is currently recognized as a branch of neurology practice [50].
- A rheumatologist. Rheumatologists are knowledgeable in managing patients with chronic pain due to inflammatory diseases of the connective tissue and musculoskeletal system, degenerative conditions of the spine and hip joints and soft tissue disorders [50].
- A psychologist/psychiatrist. Patients having chronic pain may suffer from psychological/psychiatric issues, such as depression, anxiety and post-traumatic stress disorder. Those patients can benefit from the contribution of psychiatrists in the process of evaluation and treatment. Programmes designed to overcome barriers to recovery like cognitive behavioural therapy can improve psychological well-being by changing the feelings, thoughts and beliefs of patients about their pain [50, 51].
- A physical therapists. Patients with chronic pain often try to avoid physical activity, to avoid worsening pain and/or for fear of re-injury. For this reason, physical therapy should be a part of any complex pain condition to avoid and improve complications of reduced motion [50, 51].
- Nurses will also play a significant role in the MDT. Well-trained nurses can coordinate care plans. They can assess patients for vital signs and pain scores, supervise medication regimes and conduct non-pharmacological interventions such as education, relaxation, distraction, comfort therapy, as well as other strategies [51].
- Additional MDT members might include pharmacists, dieticians, occupational therapists, educational therapists and complementary therapists [56]. In addition, primary care providers or general practitioners in nearby primary and/or secondary healthcare facilities can play a central role in the MDT, by providing long-term care planned by tertiary facilities and referring indicated patients for additional assessment and management [50].

However, several factors can represent barriers to the proper functioning of the MDT in an integrated manner. Involvement of some team members on a part-time basis, lack of regular team meetings, poor communication within the team and/or domination of the team by overbearing individuals can hinder true collaboration and make the team become dysfunctional with a possible detriment to patient [49]. A bigger issue is the question of liability in case of a patient's complication resulting from a decision given by the MDT. Unlike statutory bodies and corporations, MDTs have no official legal identity, and thus, liability will fall on individuals involved in the decision-making or provision of treatment. However, all decisions should be thoroughly discussed and taken during regular meetings. Accurate confirmation of all information presented to the MDT might be designated to a team member, preferably the primary care provider or the general practitioner as soundness of decisions depends on the precision of relevant information [57].

Once a decision is made by the MDT, it should be explained in a comprehensive manner to the patient, in order to give an informed consent. Any disagreement inside the MDT team should be formally recorded and along with its justification, should be communicated to the patient [49, 57]. Documentation of dissent can obviate the personal liability of that individual physician, should the team later be found liable [57]. Similarly, if the referring physician disagrees with the MDT decision, this should be explained clearly to the patient with justifications. Without clear explanations of the decisions and dissents, informed consents are considered invalid and litigation is more likely rated by patients. Therefore, any deviation from the treatment plan made by the MDT should be notified to all team members with an invitation for a new discussion [49].

Equipment and set-up

Interventional management of chronic spinal pain requires special settings and adequately equipped healthcare facilities ready to deal with various diagnostic and therapeutic procedures, as well as procedural complications.

Outpatient setting

1. Basic neurological and musculoskeletal examination tools are essential for the preoperative assessment of patients with spinal pain. This includes but not limited to reflex hammer, 128-Hz tuning fork, ophthalmoscope, cotton swabs, safety pins, weight and height scale and measuring tape.
2. Basic injectable (local and systemic) pain medication and corticosteroids for simple procedures including trigger point injections for myofascial pain and joint injections.
3. A pharmacy for the provision of uncontrolled and controlled pain medications according to the individual patient condition and local regulations.
4. Radio-diagnostic facility for proper radiological (radiography, computed tomography and magnetic resonance imaging) investigations of various spinal problems.
5. Physical therapy unit for proper rehabilitation programmes.

Inpatient setting

1. Intensive care unit (ICU) ready to receive and deal with rare unexpected procedural complications with an ICU bed equipped with vital and oxygen saturation monitoring and a standby mechanical ventilator machine.
2. An interventional spine and pain management suite. The wall barriers must reduce stray radiation levels outside the suite to the safe limits by adding lead at standard thickness to the room walls. The suite should provide a controlled environment with proper support space for staff and patients to function properly. The suite should be equipped with a standard radiolucent table foam pads and spinal frames.
3. Image guidance. Basically, a mobile biplanar fluoroscopy unit (C-arm) should be available for safe image-guided procedures. Alternatively, a 2D/3D imaging unit designed to meet the workflow demands of the surgical environment (like O-arm™ system) can be used to provide enhanced 3D visibility and surgical feedback, thus improving patient's safety. Ultrasound guidance of spine interventional procedures for pain has also become increasingly common, with advantages and disadvantages compared to fluoroscopy and CT guidance. However, large studies compared to these modalities are still lacking [58].
4. Protective tools for radiation exposure. Lead aprons with protective thyroid collars and protective goggles for medical staff involved in the procedures. Mobile lead shields and barriers can be used for other personnel such as fellows and circulating nurses.
5. Complete toolkits for various diagnostic and therapeutic injectates such as: nonionic radio-opaque contrast materials for proper verification of targeted tissues, anti-inflammatory agents (corticosteroids, e.g. triamcinolone and methylprednisolone) and local anaesthetics (e.g. bupivacaine and lidocaine).
6. Bone biopsy kits including coaxial biopsy needles (such as Jamshidi needles), with plunging stylets and syringes for core sample collection within the vertebral bodies.
7. Vertebral augmentation kits. Including access needles for the vertebral bodies, cement cannulae for safe delivery of cement (during vertebroplasty) with additional balloon catheter, preferably with radio-opaque markers for easier placement and detection of balloon (for kyphoplasty)
8. Percutaneous disc removal system (decompressor discectomy). This includes access needles and probes for intradiscal pressure release with minimal annular interruption.
9. Radiofrequency generator with a complete set of monopolar cannulae (straight and curved with variable gauges and lengths) and monopolar electrodes.
10. Intradiscal electrothermal therapy (IDET) system. It includes: access instruments, hollow needles and straight cannulae, in addition to an IDET generator with a thermal resistive, temperature-controlled heating coil probe to deliver the thermal energy.
11. Spinal cord stimulation system. This includes access needles for epidural space (Tuohy needle) temporary and permanent electrodes, external and implantable generators (conventional or rechargeable generators).
12. Intrathecal bumps for intrathecal delivery of narcotics and baclofen.

Principles of fluoroscopy guidance

Obtaining an adequate level-specific view

Owing to its multiple curves, each vertebral level of the spine carry has a specific spatial orientation. Therefore, the traditional straight orthogonal AP and lateral position of the fluoroscopy unit cannot provide satisfactory images for different levels. For obtaining a precise orthogonal AP and lateral views of the level of interest, the angle of the fluoroscopy unit can be adjusted along the right–left (RL) and craniocaudal (CC) axes. An adequate AP view can be obtained by tilting the fluoroscopy unit along the RL axis to bring the spinous process at the midline of the target vertebra midway between both pedicles, then tilting the unit along the CC axis till both ring epiphyses appear as straight lines. The target vertebra looks like a "box" when this procedure is done correctly. To obtain a precise lateral view, the fluoroscopy unit is placed in an orthogonal lateral position and then adjusted along the RL axis to superimpose the articular processes and profile the posterior wall as a single line, then tilting the unit along the CC axis to superimpose the pedicles and profile the endplates as single lines. Doing this correctly, the target vertebra will appear like a "box" with the intervertebral foramina clearly identified [59].

En face technique

This technique is also known as "bull's eye" or "down the barrel" technique and helps the interventionist to safely and precisely insert the needle. First, the fluoroscopy unit is angled in line with the proposed trajectory from the skin towards the target. The needle is then carefully inserted in line with the radiation beam, so that it appears as a radiopaque dot overlying the target. Alternating between AP and lateral fluoroscopy views helps identify the exact location of the needle tip during insertion and at the final position [59].

Scottie Dog projection

Lumbar percutaneous procedures often require obtaining a "Scottie Dog" view. This requires first obtaining a precise level-specific AP view with "box" vertebra. Then, the fluoroscopy unit is rotated oblique towards the selected access side until the characteristic "Scottie Dog" view is obtained [59]. The final view of Scottie Dog and its anatomical components are demonstrated in Fig. 2. Pars fracture appears in the form of a "collar" on the neck of the Scottie Dog.

Guidance for interlaminar access

This view is indicated for lumbar punctures and epidural injections. A precise level-specific AP view is first obtained. The fluoroscopy unit is tilted in the CC axis parallel to the spinous process orientation. Then, the unit is slightly tilted in the RL axis towards the planned access side to open up the interlaminar window. The target is the inferior border of the lamina at the spinolaminar junction [59] (Fig. 3).

Guidance for lumbar foraminal access

A Scottie Dog view is first obtained as previously described. The fluoroscopy unit is then manipulated in the. RL axis to bring the dog ear superimposed over the above disc space approximately two-fifths of the disc endplate length behind the anterolateral vertebral body

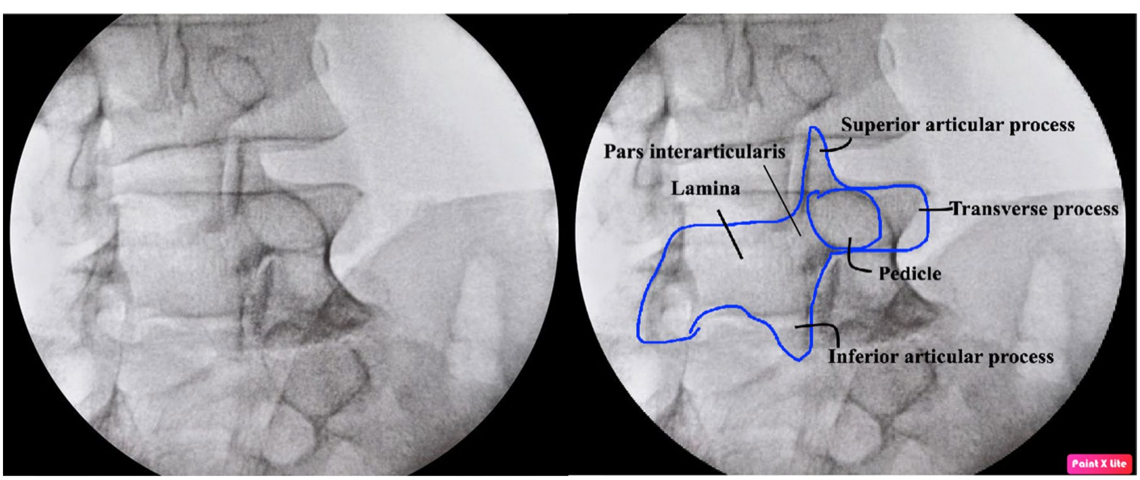

Fig. 2 Scottie Dog fluoroscopy view. The superior articular process represents the ear, the inferior articular process is the anterior limb, the transverse process is the nose and the pedicle is the eye, the pars interarticularis is the neck and the lamina is the body (Reproduced and edited from [126])

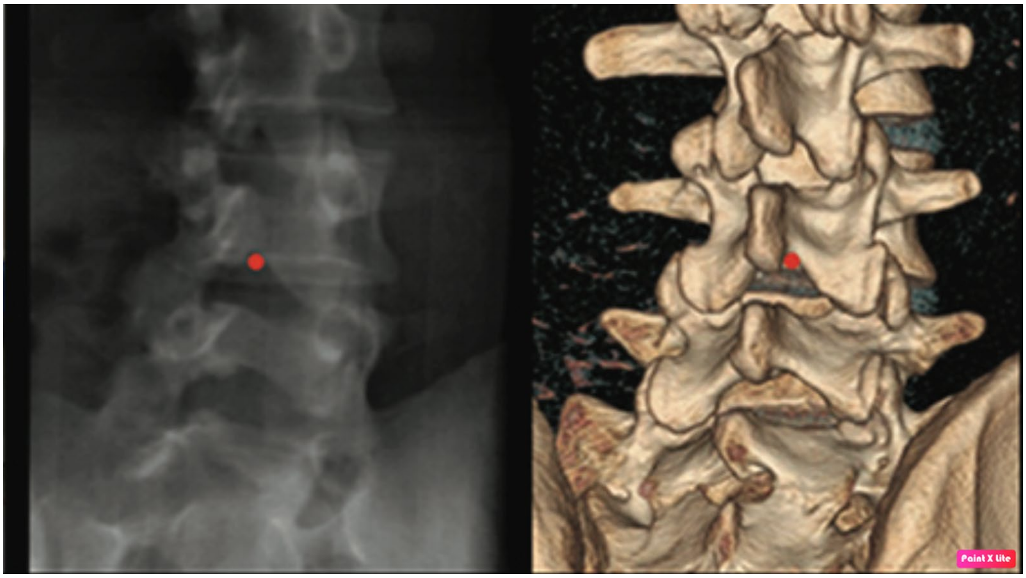

Fig. 3 Fluoroscopic view (left) and 3D lumbar CT (right) of the interlaminar access after slightly tilting the jmaging unit in CC and RL axes to open up the L4/5 interlaminar space. The inferior border of the lamina at spinolaminar junction is targeted. (Reproduced from [59])

margin. The conventional target lies immediately below the 6 o'clock portion of the pedicle (Dog's eye), within the so-called safe triangle [59]. An alternative window for injection is the Kambin's triangle which adopts a lower location of injection within the intervertebral foramen and proved to be equivalent to the traditional safe triangle in efficacy [60]. Owing to its lower location within the neural foramen, it may be preferable to use Kambin's triangle for thoracolumbar injections to avoid injuring the artery of Adamkiewicz which almost invariably course within the upper and middle portions of the neural foramen, the injury of which can result in rare but devastating complications like paraplegia [61] (Fig. 4).

Guidance for facet joint access

For a lumbar facet joint view, obtain a level-specific AP view while the patient in the prone position. The fluoroscopy unit is tilted towards the desired side of access. The angle of tilting the unit is approximately 30° for the upper and 60° for the lower lumbar spine [24]. The facet joints are designed in such a way that the posterior aspect of the joint lies further away from the midline than the anterior aspect [62]. So, during rotation of the fluoroscopy, the posterior aspect of the joint is the first portion to be

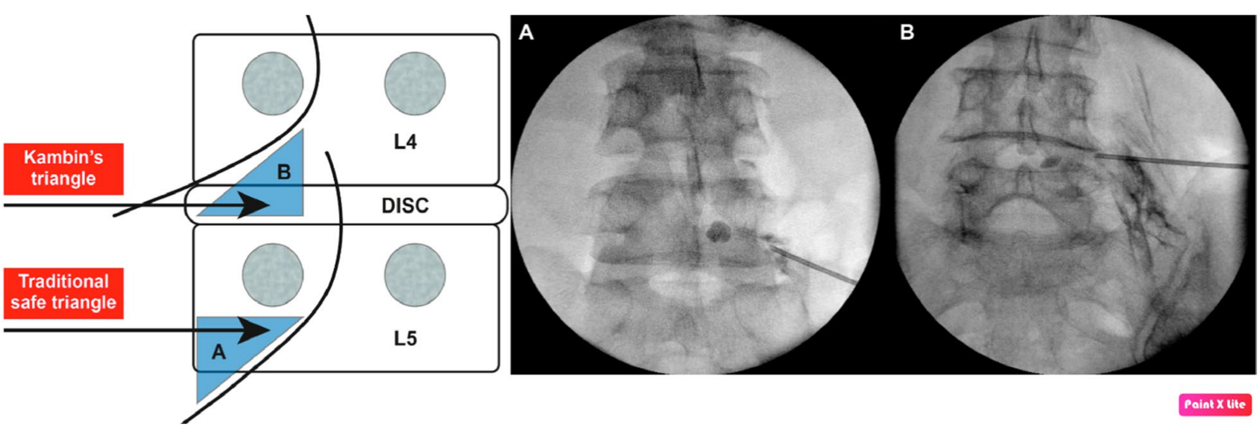

Fig. 4 Drawing on the left shows; **A** the traditional safe triangle for lumbar transforaminal injection, **B** the Kambin's triangle for lower transforaminal injections. The fluoroscopic AP views on the right show dye injection at; **A** traditional sat triangle, **B** Kambin's triangle. (Reproduced and edited from [60])

seen. Over-rotation will bring the anterior portion of the joint in view, which makes the needle placement impossible and thus should be avoided [24].

For the cervical facet view, the patient lies in the lateral position, with access side upwards, on a headrest to avoid neck lateral flexion and shoulders drawn down. The fluoroscopy unit is placed in an orthogonal AP position to obtain a lateral cervical view. Manipulation of the unit in CC and RL axes will profile a precise joint space at the desired level. The target is the posterior–inferior aspect of the joint to avoid inadvertent vascular and neural injuries [24].

Guidance for selective cervical nerve root block

Patients should have an available MRI or contrast-enhanced cervical CT prior to procedures to precisely locate the vertebral artery in relation to the neural foramen which is preferably in an anterior location for safe needle insertion. The neural foramen angle is then measured at the target level (Fig. 5C). The patient is positioned either supine or at 45° by placing a wedge-shaped sponge behind his back with the access side facing up. In either position, the spine should be kept straight to easily reproduce the measured angle at the target level and the patient's neck is raised to the eye level of the interventionist (Fig. 5A, B). First, an AP view is obtained for the target level with the spinous process lying midway between the lateral masses. The fluoroscopy unit is then tilted in the RL axis to the measured foramen angle. The fluoroscopic view will reveal the pedicles with easily identified intervertebral foramina that can be counted down from the highest foramen (C 2–3 level) down to the target neural foramen (Fig. 1B). A curved clamp is then used to identify the targeted posterior–inferior aspect of the neural foramen by placing its tip gently on the skin (Fig. 5D). Firm pressure of the clamp against the skin is avoided as this may result in a non-representative mark once the skin recoils. Fluoroscopic confirmation of the trajectory of the needle is performed during the procedure till reaching the final desired position of the needle tip [63] (Fig. 5E, F).

Guidance for lumbar disc access

This view is required for intradiscal procedures of L1-2 to L4-5 levels like disc decompression, disc biopsy and discography. After obtaining a true AP view "box" of the target level, the fluoroscopy unit is tilted in the RL axis to reveal the "Scottie Dog" view. The unit is oriented so that the superior articular process (dog's ear) bisects the vertebral endplate overlying the mid portion of the disc space. Further obliquity allows for a more posterior access to the disc but carries the risk of violating the thecal sac, while less obliquity results in an inappropriate peripheral disc access and may injure the nerve root. With proper fluoroscopic obliquity and patient's position, the target will be just in fort of the superior articular process in the disc centre [59] (Fig. 6, upper).

On the other hand, L5-S1 disc space is in terms of the narrow window of access between the superior articular process of S1, inferior endplate of L5 and the iliac crest. First, an AP view of L5-S1 disc level is obtained. Due to the local lordosis the fluoroscopy unit is rotated in the CC axis to profile first the lower L5 endplate. Further inclination of the unit will profit the upper S1 endplate. The optimal angle is between these two bony landmarks. The imaging unit is then tilted in the RL axis till the superior articular process of S1 is superimposed over the midpoint of S1 superior endplate and the iliac crest is seen as a curved line projected lateral to S1 superior articular process. The target is the small radiolucent triangle bordered by the lower endplate of L5 above, the S1 articular process medially and the iliac crest laterally [59] (Fig. 6, lower).

Guidance for transpedicular vertebral body access

The "box vertebra" view is first obtained by adjusting the fluoroscopy unit along the CC and the RL axes while the unit is oriented in an orthogonal AP projection. The unit is then tilted towards the access side to profile the "Scottie Dog" view. The target is the centre of the pedicle (dog's eye) which overlies the superior portion of the vertebral body limited by the boundary of the superior endplate. Tilting the imaging unit to variable degrees in the CC axis superimposes the dog's eye over the superior or inferior halves of the body and thus, allows for final targets with upper or lower portions of vertebral body. Tilting the unit along the RL axis allows access to ipsilateral, middle or contralateral portions of the vertebral body [59] (Fig. 7).

Guidance for sacroiliac joint access views

For the classic oblique access, the fluoroscopy unit is initially placed in a direct AP view, and then a contralateral tilt of 5°–15° in the RL axis is used to obtain alignment of the anterior and posterior joint lines. For the posteroanterior access, the fluoroscopy unit is initially placed in an AP view, allowing for visualization of both the anterior and posterior joint lines, then the unit is tilted in 5°–15° cephalad in the CC axis to better expose the lower pole of the posterior joint line [64] (Fig. 8).

Interventional procedures

1. Trigger points injections

These are the most basic injections and are known to help myofascial pain using combinations of different pharmaceutical agents such as steroids, local

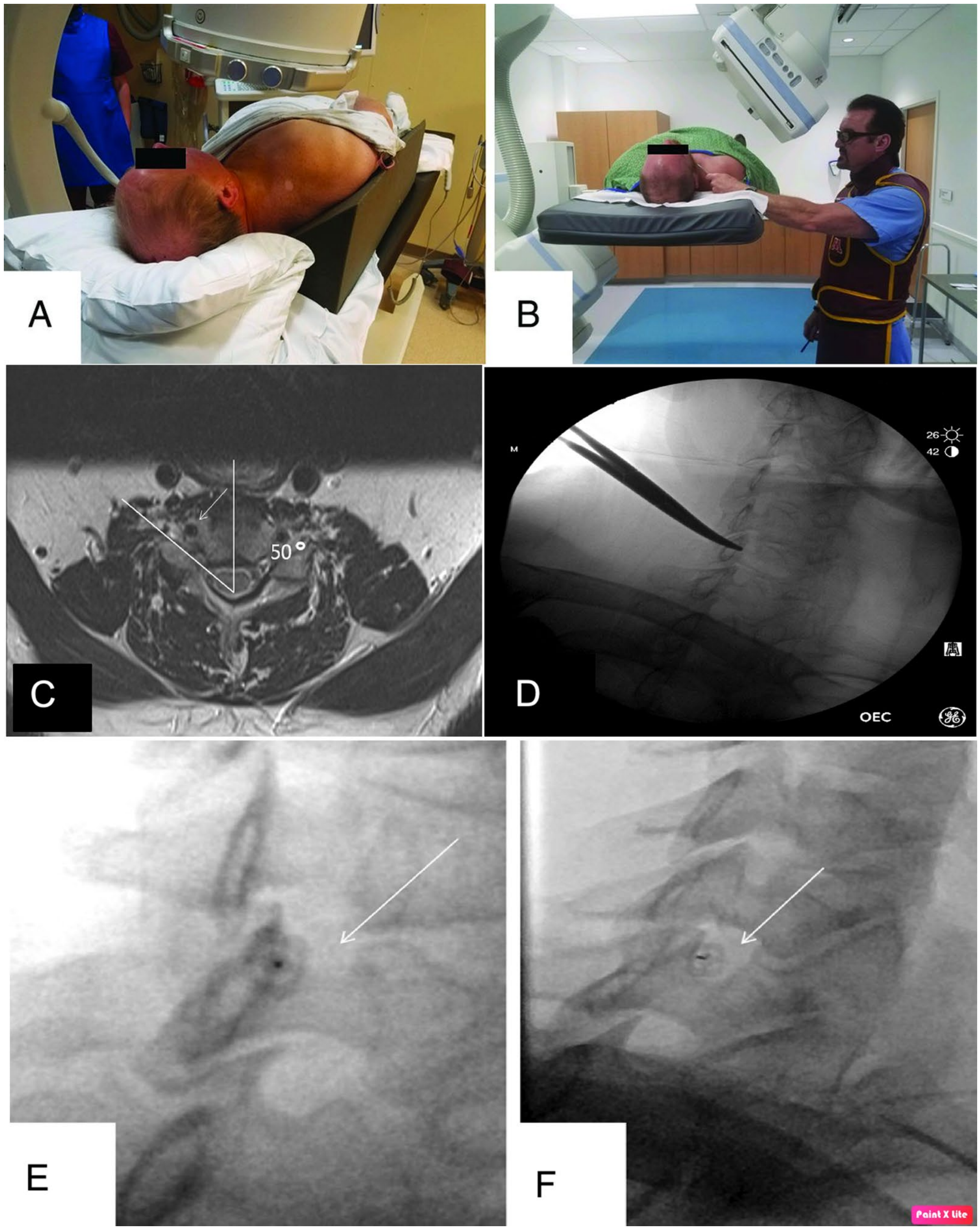

Fig. 5 **A** and **B** The proposed positions of the patient during selective cervical nerve block either oblique "A" or supine "B" at the level of the interventionist eyes. **C** The pre-procedural measured angle of the targeted neural foramen. The white arrow points to the vertebral artery which lies anterior to the foramen allowing for a safe trajectory for the needle. **D** Identification of the posterior–inferior aspect of the foramen by placing a curved clamp over the skin with the projected tip at the desired location. **E** The ideal position of the needle tip at the posterior–inferior aspect of the foramen. The needle is inserted using en face technique in line with the radiation beam, thus appearing as a radio-opaque dot. **F** Slightly higher, yet an accepted position of the needle tip. (Reproduced and edited from [63])

anaesthetics, opiates and botulinum toxin. (Botox) The affected muscle is injected at various tender points as identified by palpation followed by stretching exercises to achieve long-term relief of pain. Dry needling is used by some practitioners and found equally effective when combined with physical therapy [65].

2. Epidural injections

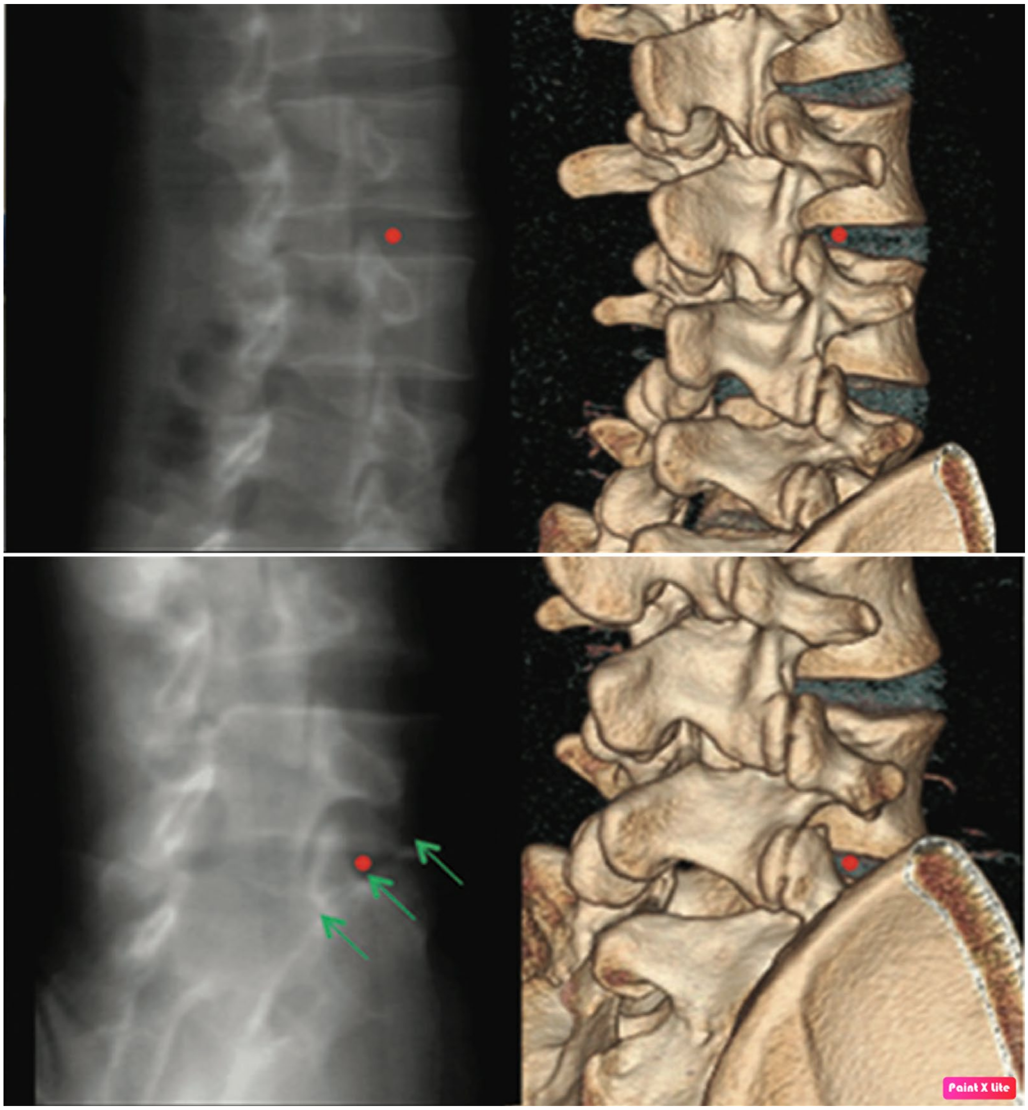

Fig. 6 Above, the proper fluoroscopic view and target "red dot" for access of L1-2 to L4-5 disc levels. Below, the proper view for L5-S1 disc space access showing the triangular window medial to the iliac crest "green arrows" and the ideal target location "red dot". (Reproduced from [59])

a. Interlaminar epidural injection

This is the most common procedure performed blind; however, fluoroscopic guidance is recommended to ensure the correct level and side and avoid intra-arterial injections. The interlaminar space is targeted at spinolaminar junction guided by the "sudden release" or "loss of resistance" technique when resistance to air injection by an attached string marks the entrance into the epidural space. Injection of contrast for fluoroscopic confirmation. The injectate is a combination of the intended dose of corticosteroids with a local anaesthetic/normal saline mixture for better coverage of inflamed tissue. Lumbar interlaminar epidural injections were found effective in patients with disc herniations or radiculitis using local anaesthetic regardless of steroids. Steroids showed superiority over local anaesthetic alone at 1-year follow-up [66]. In a systematic review, the authors found good evidence for lumbar epidural injections for radiculitis secondary to disc herniation with local anaesthetic and steroids and fair evidence with only local anaesthetic. The evidence was fair for radiculitis due to spinal stenosis with local anaesthetic and steroids, and fair for axial pain without disc herniation with local anaesthetic regardless of steroid use [67].

b. Transforaminal epidural injection

This procedure targets pain secondary to nerve root inflammation which sometimes associates with axial

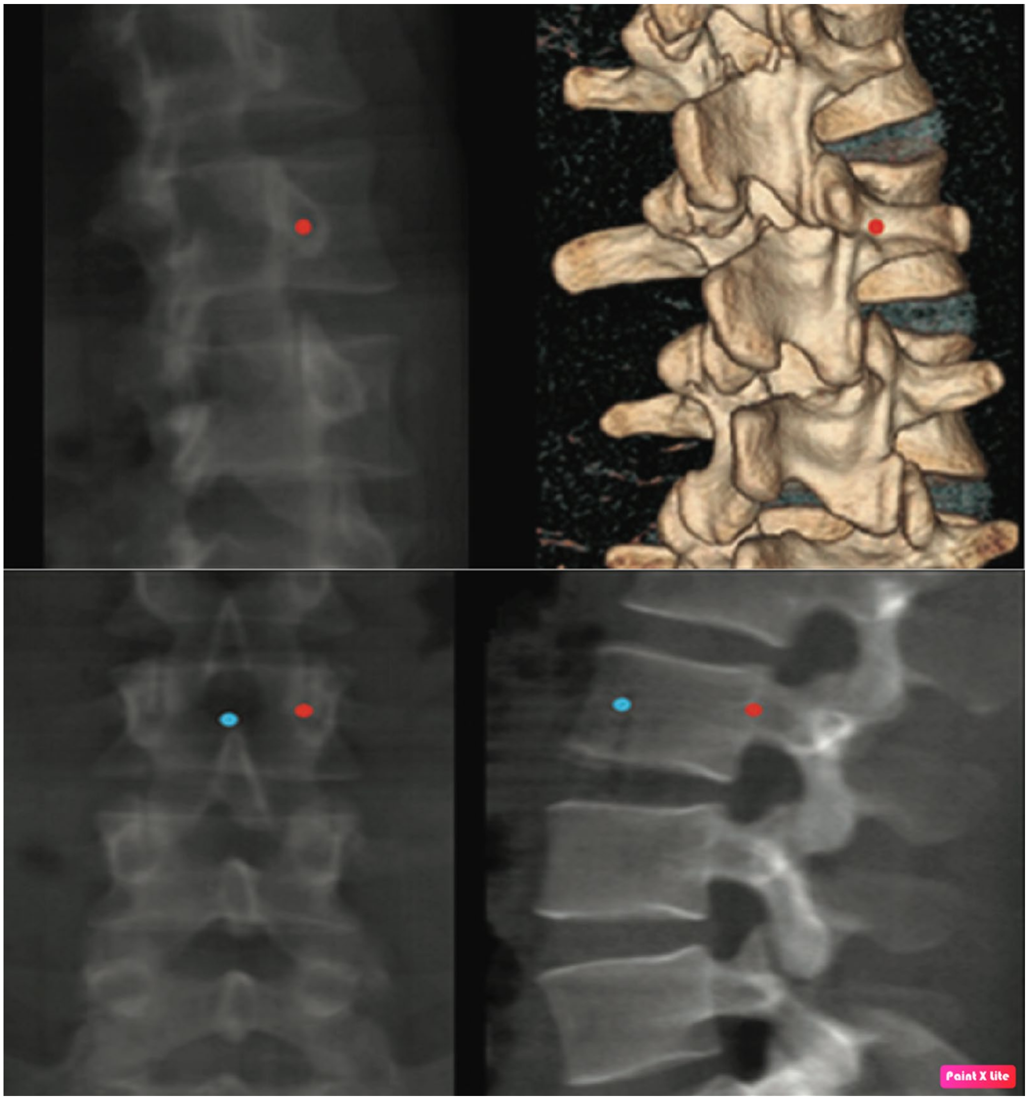

Fig. 7 Fluoroscopic view for transpedicular access to the vertebral body. Upper views show the target point "red dot" at the centre of the "Scottie Dog" eye. Lower views Identify the safe margins during insertion of the needle. During pedicle trajectory, the medial cortex of the pedicle is considered the safe medial limit on AP view (red dot in lower left view) until the posterior vertebral wall is passed on the lateral view (red dot in the lower right view). Inside the body, the needle can be advanced towards the midline in AP view (blue dot in lower left view) and the safe limit is the junction between the anterior and middle thirds of the vertebral body in lateral view (blue dot in lower right view). (Reproduced from [59])

neck and low back pain. The needle targets the inferior portion of the intervertebral foramen and medication (steroids/local anaesthetic) is delivered after fluoroscopic confirmation. Manchikanti suggested that the evidence in favour of therapeutic transforaminal steroid epidural injection in managing chronic low back pain is less controversial and more balanced than diagnostic blocks and blind interlaminar epidural injections [65, 68].

c. Caudal epidural injection

One of the most commonly performed procedures, frequently done blindly depending on palpated anatomical landmarks. Used for post-operative spinal pain and cases with severe spinal stenosis or degeneration, in which interlaminar access is not feasible. An epidural needle is used via a midline approach to access sacral epidural space, halted at the S3 level to avoid penetration of the dura, which usually extends up to the S2 level but can be lower. After fluoroscopic confirmation of position using contrast, the corticosteroid can be injected [65].

In a recent systematic review, Parr et al. found that the evidence for caudal injection was fair in managing chronic axial pain, spinal stenosis, and post-operative syndrome; however, it was good for short-term and

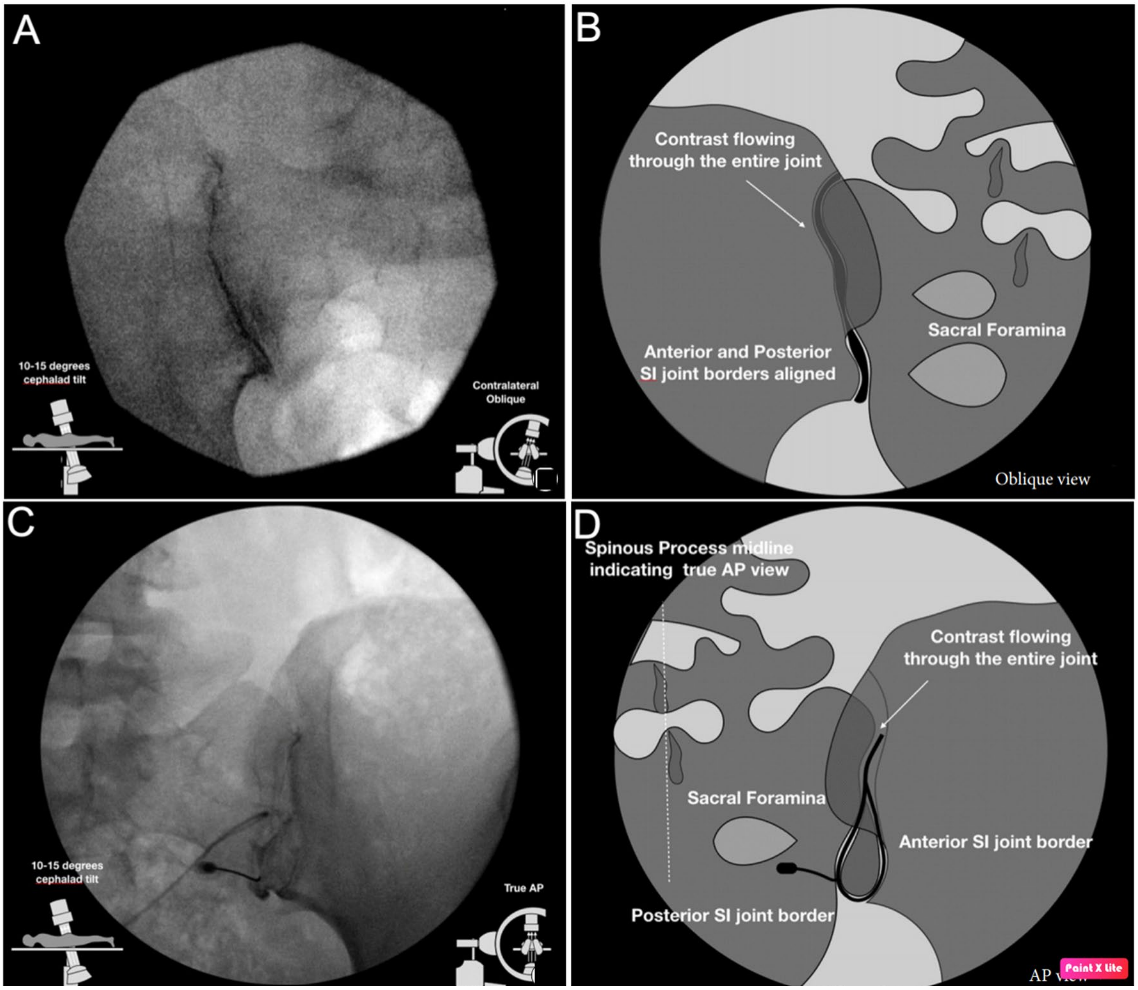

Fig. 8 Oblique technique fluoroscopic view (**A**) and graphical illustration (**B**). In the oblique approach, the C-arm is rotated in a contralateral manner until the 2 joint lines become superimposed. Then, one would target the inferior segment of this superimposed image, as the superior sacroiliac (SI) joint space is composed of interosseous ligaments. Antero-posterior technique fluoroscopic view (**C**) and graphical illustration (**D**). In the anterior–posterior (AP) approach, image is taken with 5°–15° cephalad tilt from the vertical of the fluoroscopy machine reveals a joint with 2 separately visible anterior and posterior joint lines. The anterior and posterior parts of the sacroiliac (SI) joint were delineated as lateral and medial joint spaces, respectively. (Reproduced from [64])

long-term improvement in chronic pain secondary to disc herniation/radiculitis with local anaesthetic and steroids. They also reported that it was more effective than transforaminal and interlaminar approaches [69].

3. Facet joint interventions

a. Medial branch block

Facet nerve block is a very important step in exploring pain generators in the functional spine unit, because facets are common sources of pain and medial blocks are easily performed procedures [70]. Facets can be approached by obtaining the "Scottie Dog" profile and targeting the junction between the transverse process and the superior articular process where the medial branch lies. This corresponds to the eye of the "Scottie Dog". After confirmation of the target using contrast medium injection, a small amount (to avoid false-positive results), usually 0.5 ml of local anaesthetic, is injected [65]. A single needle can block multiple levels [71].

b. Medial branch radiofrequency neurotomy

Radiofrequency ablation of the medial branch usually follows a successful positive facet block to achieve long-term relief of pain. The two medial branches supplying each facet should be ablated to achieve adequate facet denervation. This is achieved by choosing an adequate needle (usually 18–22 G, with a 10-mm active tip) better placed tangential to the target for maximum contact with the nerves with a radiofrequency lesion carried for 60–90 s at 60–80 Celsius. A small amount of anaesthetic is injected at target before ablation to minimize procedural discomfort and the tip of the needle should not encroach upon the foramen in lateral fluoroscopic new to avoid exiting nerve damage [65, 72].

c. Intra-articular injections

Recently pain physicians are losing interest in this procedure whose effectiveness proved to be of limited evidence [40]. It can be reserved for those who cannot perform radiofrequency ablation due to the presence of a pacemaker or prior insertion of spinal cord stimulator.

4. Sacroiliac joint interventions

a. Sacroiliac injections

The capsule and ligaments surrounding this joint is well innervated with nociceptive fibres and can be accessed at its lower 1/5 to 1/3 portion under fluoroscopic guidance. After obtaining a fluoroscopic view, the needle is introduced beyond the ligaments into the space with injection of a small amount of contrast to confirm interarticular position (linear spread of contrast) with additional confirmation of the depth using lateral fluoroscopic view. A maximum of 1 ml of injectate which is a combination of local anaesthetic and steroids is introduced [65].

b. Sacroiliac neuro-ablative procedures

(1) Cooled radiofrequency ablation

This procedure generates large spherical lesions that can reach and ablate the supplying nerves that are usually floating higher than the osseous surface at this region. It is a time-consuming procedure, where multiple levels are targeted with 3 lesions (e.g. at 2, 4 and 7 O'clock on the right side) to be generated lateral to the sacral foramen at each level, in addition, to L5 medial branch at the level of the ala of the sacrum. Promising, durable (20 months) pain relief with improved quality of life and medication use was reported with this procedure [73].

(2) Thermal radiofrequency (RF) ablation

This procedure uses bipolar technique using 2 RF needles (5 mm apart) targeted along the medial aspect of the SIJ where supplying nerves are near the osseous surface. The technique is effective in controlling SIJ pain; however, it has lower evidence for efficacy than cooled ablation technique [65].

5. Vertebral body interventions

a. Vertebral biopsy

Vertebral lesions (particularly secondaries) can be a source of severe axial pain. In absence of an obvious primary source, vertebral biopsy is of paramount importance to confirm the diagnosis and direct the management plan. A coaxial system through a fluoroscopic-guided transpedicular access can obtain multiple samples through one entrance point. Accuracy and complications were found to rise with the inner diameter of the used cannulae [74].

b. Vertebral augmentation (vertebroplasty and kyphoplasty)

Vertebral augmentation is most frequently used to treat osteoporotic compression fractures associated with persistent intractable pain not responsive to medical management. Most studies report equivalent pain relief and function scores provided by both techniques. The choice of vertebroplasty may be promoted in patients with older ages, older fractures and multiple-level fractures. Kyphoplasty provides the additional benefit of vertebral height restoration and thus improves biomechanical alterations. New advancements include nitinol endovertebral cages, peek cages, vertebral body stents or polyetheretherketone implant cages [75].

c. Vertebral lesion ablation

Thermal ablation of vertebral lesions including radiofrequency, microwave and cryoablation can be used as palliative and sometimes curative modalities and provide an adequate control of associated spinal pain [75].

6. Intervertebral disc interventions

a. Provocative discography

Despite remaining a controversial procedure, provocative discectomy is able to add to the diagnostic workup to find the patient's pain generator [70]. After obtaining a fluoroscopic-guided access to the posterolateral aspect of the disc, the contrast material is injected in a graduated controlled manner and pressurized to increase intradiscal pressure and simulate pain-producing activities. The opening pressure, pain-inducing pressure, maximum pressure and pain score of the patient are estimated. Interpretation of the test depends on concordance and intensity of pain. Excess pressure generation should be avoided as it can produce rupture of enraptured disc and thecal sac compression [76].

b. Intradiscal procedures

Various intradiscal interventions with their underlying techniques and descriptions are summarized with their descriptions [75] in Table 1.

7. Intrathecal infusion devices

Since mid-1990s, this modality gained popularity for use in non-cancer pain. It involves the placement of a catheter inside the dural sac connected to a subcutaneously implanted pump (programmable or non-programmable). The device delivers a desired or fixed amount of injectate, the only FDA approved are morphine sulphate, ziconotide and baclofen [65].

8. Spinal cord stimulation (SCS)

Although its efficacy has been reported by several studies, its use in pure low back pain is controversial as it was used in the majority of these studies in patients having leg pain in addition to low back pain. Moreover, it has been used in combination with other modalities to achieve satisfactory relief. Initially, temporary leads (2 or more) with multiple contacts are placed at L1-2 level via an access

Table 1 Percutaneous interventional disc procedures (Santiago et al. [75])

Intervention	Technique	Description
Thermal decompression	Percutaneous laser decompression	Laser energy vaporizes a small volume of nucleus pulposus
	Intradiscal electrothermal therapy	Flexible thermal resistive coil (electrode or catheter) coagulates the disc tissue with radiant heat
	Intervertebral disc nucleoplasty	Bipolar radiofrequency energy causes molecular dissociation and dissolves nuclear material
Mechanical decompression	Automated percutaneous lumbar discectomy	Pneumatically driven suction-cutting probe
	Percutaneous disc decompression	Mechanical high rotation per minute device with spiral tips or metallic laminae or water-driven suction-cutting probe
	Percutaneous discectomy	Herniotome extracts hernia or portion of the hernia to decrease pressure on the nerve root
Chemical decompression	DiscoGel	Gelified ethanol causes dehydration of nucleus pulposus
	Ozone therapy	Ozone's chemical properties and the reaction of hydroxyl radical with carbohydrates and amino acids leads to breakdown of nucleus pulposus
Biomaterial implantation "regenerative injection treatment (RIT)"	Hydrogel, platelet-rich plasma, and stem cell therapy	Aim: intervertebral disc regeneration

needle using the release technique into the epidural space under fluoroscopy guidance. The leads are advanced up to T8-9 level and connected external temporary stimulator for 3–10 days, to be replaced, after successful pain relief, by permanent leads connected to an implantable subcutaneous conventional or rechargeable generator [65].

9. Peripheral nerve field stimulation (PNFS)

A relatively new modality that uses neuromodulation is combined with spinal cord stimulation for better control of chronic axial pain. It is commonly used in failed back surgery syndrome, where multiple stimulator leads are inserted subcutaneously around the painful aspect of low back in conjunction with centrally placed SCS leads. The proper depth of leads for subcutaneous stimulation is still not clear despite some trials to standardize it [77].

10. High-frequency stimulation for low back pain

It uses the conventional placement of the spinal cord stimulation device but with different programming to generate higher frequency current (up to 10 kHz), which is thought to be of higher effectiveness for pain relief with no associated sensory paraesthesia [78].

Algorithmic approach to chronic spinal pain

Proper history, physical examination, and MDT discussions are essential to provide appropriate documentation, adequate decisions and best patient care. Added to these factors are the socio-economic issues and psychosocial aspects that are very important in the clinical decision-making.

Low back pain diagnostic algorithm

In the presence of evident radiculopathy or spinal stenosis with radicular component, the interventionist can proceed with therapeutic epidural or diagnostic transforaminal injections [79]. Otherwise, an algorithm for detection of the pain generator is followed in which the facet joints are targeted first, owing to their commonality and higher evidence in low back pain (level 1 or level II-1) [80], in addition to available treatment and ease of performance [70]. Medial branch block has the best evidence (Level 1) with the ability to roll out false positives [81]. More than one block is performed during the same session (bilateral or sequential) based on clinical presentation as multiple facet involvement is documented [70]. A positive response is considered if 80% of at least 80% pain relief is experienced with the ability to carry on previously painful movements within a time frame appropriate to the local anaesthetic duration. A negative facet block will direct the algorithm towards either SIJ or epidural injections. To start with SIJ injection a clinical suspicion should be available such as Pain caudal to L5, local tenderness over SIJ and positive provocative tests (at least 2 tests) for SIJ pain [82]. One or both SIJ may be blocked, and a positive response is defined on the same basis as facet blocks, with bupivacaine injection outlasting lidocaine injection [70]. Epidural injection (interlaminar and caudal) comes next if SIJ injections are negative or SIJ pain is not clinically suspected after negative facet blocks. At least 2 fluoroscopically guided epidural injections are performed before considering negative injection [70].

Provocative lumbar discography can be performed after all previous injections are negative due to the low sensitivity and specificity of different tests, including imaging modalities to identify whether or not the disc is the primary pain generator of low back pain [83]. Provocative discography is rarely done as an initial test, except in the setting of high clinical suspicion before definitive treatment such as spinal fusion is provided [70]. Provocative discography is considered valid when concordant pain in one disc is encountered with at least 2 negative its, one above and one below, except for L5-S1 where only one negative disc is required with the index level (L5-S1 disc) displaying evoked pain with intensity 7/10 on Numeric Pain Rating Scale or 70% of the worst spontaneous pain [84]. With this algorithm, approximately 70% of patients with low back pain undergo facet blocks, with approximately 30% positive results with no further investigations needed. Of the remaining 70%, about 10% will require SIJ blocks and perhaps 30% will prove positive. The remaining 60% of 70% (with negative SIJ blocks) and original 30% not undergoing facet blocks—overall 60–70%—will undergo epidural injections and about 65% will respond to injections and 20% of the remaining 35% will be candidates for provocation lumbar discography if a definitive treatment can be provided [70].

Low back pain management algorithm

Patients with positive facet blocks can undergo either radiofrequency neurotomy (Level II-2 to II-3 of evidence) or therapeutic facet joint nerve blocks (Level II-1 to II-2 of evidence) according to patient preference, physician expertise or available treatment [85, 86]. No evidence to support lumbar interarticular injection is available in the literature [80]. For patients responsive to epidural diagnostic injections, caudal epidural injection can provide relief of chronic back pain secondary to disc herniation or radiculitis and discogenic pain without herniation (Level I) and chronic post-laminectomy or spinal stenosis back pain (Level II-1 and II-2) [87]. Therapeutic lumbar transforaminal epidural steroid injections can achieve short-term relief (Level II-2) and long-term relief (Level II-2) of chronic lumbar radicular pain [88]. However, lumbar interlaminar epidurals provide short-term relief (Level II-2) of the pain of disc herniation or radiculitis with a lack of evidence for other conditions [89]. Therapeutic sacroiliac joint interventions can provide pain relief (Level II-2), while sacroiliac joint neurotomy showed no evidence [70, 82]. Finally, limited evidence was found for intradiscal procedures in chronic back pain. A systematic review in 2009, found Level II-2 evidence for IDET and a Level II-3 evidence for radiofrequency annuloplasty, while no or limited evidence for intradiscal biacuplasty [90]. Moreover, IDET carried higher efficacy than radiofrequency annuloplasty when compared together [91]. However, a recent systematic review in 2017 found that evidence is strong (Level I) that percutaneous biacuplasty is effective in treating chronic refractory discogenic back pain, recommending its use as a first-line in refractory cases [92]. Patients with chronic non-responsive back pain may also be considered for percutaneous adhesiolysis, percutaneous disc decompression (including automated percutaneous discectomy, percutaneous laser discectomy, high RPM "decompressor" device and nucleoplasty) spinal cord stimulation or implantation of intrathecal infusion systems [70]. A recent systematic review has reported the potential beneficial effects of nucleoplasty and the increasing success rates of automated percutaneous discectomy and percutaneous laser discectomy in selected patients with limited evidence for DeKompressor disc device [91]. Another recent systematic review reported the promising safe role of spinal cord stimulation in patients with chronic back pain who have not undergone prior surgery [93]. Implantable intrathecal infusion systems revealed Level II-3 to Level III evidence for long-term relief in chronic back pain [94].

Neck pain diagnostic algorithm

The algorithm starts with careful history taking, proper neurological investigations and adequate imaging studies. The facet joints are targeted first by diagnostic blocks because of commonality and ease of performance with an estimated prevalence rate of 39% and a false-positive rate of 45%. Facet joint pain was found to be bilateral with at least 3 joints affected in more than 50% of cases [95]. Diagnostic blocks are performed using 2 separate local anaesthetics, and 2 blocks are performed provided the first one is positive. A positive diagnosis is made if 80% relief was achieved with the ability to perform previously painful movements for a duration concordant with 2 different local anaesthetics [70]. Negative facet blocks indicate a cervical interlaminar epidural injection. Failure to respond to at least 2 fluoroscopically guided epidural injections may indicate proceeding to cervical discography [70]. Despite being controversial regarding its utility and its inferiority to lumbar discography in establishing diagnostic accuracy, provocation discography is still the only tool that can determine whether or not a particular disc is the pain generator irrespective of imaging findings [70]. To be considered valid, discography should provoke concordant pain in one disc with at least 2 negative levels, with evoked intensity of pain of 7 out of 10 on the Numeric Pain Rating Scale or 70% of worst spontaneous pain [84]. Discogenic pain counts for 20% of cases with chronic neck pain and provocative discography is performed at a final step after the failure of fact blocks and epidural injections and performed only when appropriate treatment can be provided after. Demonstration of disc abnormality [70].

Neck pain management algorithm

Patients with positive facet blocks can undergo either a therapeutic facet (medial branch) nerve blocks (Level II-1 evidence) or a radiofrequency (medial branch) neurotomy (level II-2) according to the patients' preferences, treatment availability and physician expertise. However, no evidence for cervical intra-articular facet joint injections is available [96]. Cases with revealed discogenic pain may be referred to interlaminar epidural injections or surgery with the stoppage of further interventions [70]. Some studies have demonstrated the effectiveness of cervical epidural injections in discogenic pain [97, 98]. Associated radicular cervical pain can also benefit from interlaminar epidural injections as their initial treatment [70], as transforaminal epidural injections lack evidence with associated increased risk [79]. Chronic persistent cases of neck pain can be referred to spinal cord stimulation or intrathecal infusion systems as recommended by an algorithm proposed by Manchikanti et al. [70], although the evidence of these modalities in neck pain has not been assessed.

Interventional management of coccydynia

Although coccydynia is primarily treated conservatively, patients that do not respond to initial conservative therapy are indicated for interventional therapy. Unfortunately, no standard treatment guidelines exist, and the results of the available studies are inconsistent. Interventional therapy includes local injection of steroids and local anaesthetics, caudal epidural block, neurolysis of sacral nerve roots, pulse radiofrequency (PRF), ganglion impar block, intra-rectal massage and manipulation, levator ani massage and stretching, and coccyx manipulation [99]. Coccygectomy is indicated for those who do not respond to interventional therapy with success rates between 50 and 91% [100, 101].

Ganglion impar is the caudal end of sympathetic chains that join at the sacrococcygeal joint. Fluoroscopic-guided ganglion impar block can be performed via a transsacrococcygeal approach using a combined steroids and bupivacaine injectate, to fulfil at least 50% pain relief lasting for a median duration of 6 months in 82% of patients [102]. Radiofrequency ablation of ganglion impar was also reported as a successful intervention under fluoroscopic guidance through the sacrococcygeal ligament, with greater than 50% pain relief in 75% of patients at 6 and 12 months of follow-up [103]. Dalbayrak et al. classified patients in their study according to Postacchini and Massobrio classification into 4 types and found that local injection of steroids and local anaesthetic may benefit only types I and II. All patients with types III and IV were offered coccygectomy [104]. Extracorporeal shock wave therapy (ECST) has been tested for treating coccydynia [105, 106]. In a prospective study, ECST relieved pain significantly on pain scale at the end of the follow-up period and improved moderate to severe disability on ODI score in 91.6% of patients [107].

Complications of interventional procedures

Generally, serious complications from interventional spine procedures are rare, with reported incidence rates ranging from 0 to 0.2% [108, 109]. Serious complications of epidural steroids particularly may include; direct neural injury, spinal cord infarction/stroke, abnormal bleeding, spinal infections, local neurotoxic and systemic allergic reactions [110–113]. Immediate overall adverse events during interventional spine procedures were investigated among 26,061 consecutive patients. They were reported to occur in 1.9% of procedures with vasovagal reactions being the most frequent event (1.1%) and less than 0.1% requiring transfers to emergency department for symptomatic hypertension, chest pain, allergic or vasovagal reactions [114].

In an anonymous online survey among Spine Intervention Society (SIS) physician members, 19.7% of respondents reported personal knowledge of complications, most commonly meningitis and spinal abscess, followed by spinal cord injury/stroke in association with transforaminal epidural injection. Reported infections were associated in 78% of cases with high-risk factors for infection (such as diabetes, HIV, drug abuse and immunosuppression). The same study reported 4 cases with neurotoxic effects related to the use of gadolinium-based contrast medium [115]. Such events had recently drawn attention to the neurotoxic effects of this type of contact media [112].

Radiation safety for interventional procedures

During interventional procedures, fluoroscopy is routinely used for the safe performance of these interventions. This results in radiation exposure with its associated risk for both the patients and the healthcare team. However, adoption of mitigation tactics for radiation exposure can reduce it by more than 90% [116]. The first and best way to reduce radiation exposure to the health staff is to reduce radiation exposure to the patient. Scattered radiation from the patient is the main source of radiation to the staff. A guiding principle to achieve radiation safety is "ALARA" principle. This stands for "as low as reasonably achievable", that means avoidance of exposure to radiation that has no direct benefit, even in small doses [117].

Radiation exposure carries both deterministic and stochastic effects. Deterministic effects are dose-dependent above a threshold. The threshold is subject to biological variation and varies individually. Deterministic effects include for example; skin injury, cataracts and hair loss.

The reported frequency of injury is between 1:10,000 and 1:100,000 procedures [118]. In stochastic effects, the severity of the effect is independent of the total dose; however, its probability rises with the dose increase. Radiation-induced cancer is an example of this defect, although its probability is small compared with the natural frequency of malignancies [119]. When treating young population or performing procedures involving radiosensitive organs, consideration of stochastic effects in the risk–benefit analysis is crucial.

Radiation safety can be fulfilled through three basic protective measures: time, distance and shielding. As radiation exposure accumulates with the time of using the fluoroscopy, reduction in usage time is of paramount importance to fulfil radiation safety for both the patient and the health team [120, 121]. This can be achieved via good planning for the procedure, as well as improved skills of the physician and the radiographer, in order to obtain adequate images as regard location, timing and quality. The physician should also consider the distance separating him from the radiation source, because the radiation exposure is inversely proportional to the square of the distance [120, 122]. Exposure of the radiographer can be reduced by about 80% by staying behind the mobile support structure by two steps [122]. Keeping yourself 20 cm farther from the X-ray field centre can reduce exposure by 73% [123]. In addition to these measures, the use of shielding devices can further add to radiation safety. These devices include for example; aprons, lead glasses, caps, thyroid shields and radiation-reducing gloves. The rate of using aprons and thyroid shields by pain physicians can be high; exceeding 80% [120, 124, 125], while the use of lead glasses and gloves is lower, estimated to be about 40% and less than 35%, respectively [124]. The shielding devices are expensive and their use can be uncomfortable; however, they are essential for radiation safety of the healthcare team.

Conclusion

Interventional spinal procedures include a diversity of management tools that can add much to the spine surgeon's armamentarium during the treatment of low back and neck pain. Interventional management should be provided through a highly qualified and dedicated multidisciplinary team, in well-equipped healthcare facilities, under imaging guidance in a controlled environment for the best patient care and safety. The concept of "functional spine unit" should replace the "single pain generator" model, dealing with the various spinal elements as a single unit functioning together with interaction between its components. This calls for the development and implementation of standardized algorithmic approaches for the diagnosis and management of neck and low back pain that failed conventional management and not indicated for surgical intervention. The literature on interventional management is expanding; however, evidence for some currently used procedures is still lacking and a call for further research studying newly introduced procedures is ringing. All interventionists should follow the radiation safety measures of time, distance and shielding to minimize radiation exposure and risks.

Abbreviations

IVD	Intervertebral disc
FJ	Facet joint
SIJ	Sacroiliac joints
AP	Anterior–posterior
OA	Osteoarthritis
RIT	Regenerative injection treatment
FSU	Functional spinal unit
MDT	Multidisciplinary team
IDET	Intradiscal electrothermal therapy
CC	Craniocaudal
RL	Right–left
SCS	Spinal cord stimulation
PNFS	Peripheral nerve field stimulation
RPM	Round per minute
ECST	Extracorporeal shock wave therapy

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