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REVIEW

Imaging of post-operative spine in intervertebral disc pathology

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Abstract This work is an imaging review of spine after surgery with special regard to imaging modality in intervertebral disc pathology. Advances in imaging technology can be evaluated. Depending on the clinical question is asked to the radiologist, it is possible to evaluate post-operative patients with conventional radiology (X-ray), computed tomography and magnetic resonance. Main indications for each technique are analysed. Imaging is important in the diagnosis of many forms of spine pathology and plays a fundamental role in evaluating post-surgical effects of treatments, according to the imaging method which is used, both on spine and on its surrounding tissues (intervertebral discs, spinal cord, muscles and vessels).

Keywords Spine · Post-operative spine · Disc herniation · X-ray · CT · MRI

Introduction

Innovations in surgical techniques and devices over the past decade make an increase in post-operative radiological exams [1]. This increase corresponds to more pre-operative imaging studies necessary to surgeons in the choice of surgical techniques and devices, in accordance with patient symptoms, anatomy, congenital or acquired familial conditions, and more post-surgical controls [2–13]. In fact with new materials and designs, there are potentially new complications to detect on conventional radiography (X-ray), computed tomography (CT) and magnetic resonance imaging (MRI). This article will offer a review of current literature on this topic, especially in post-operative disc pathology [14].

Conventional X-ray

Conventional X-ray study remains the modality of choice for long-term surveillance of spine hardware. Generally patients are re-examined clinically and radiologically (anterior-posterior and lateral standard radiography) within the first 6 weeks and 3 months after surgery.

Conventional X-ray is low-cost, easy to perform, has a wide availability and can easily be performed to assess positioning of devices or disposition of the materials used in spine surgery or interventional procedures (i.e., bone cement in cases of vertebroplasty) [15, 16].

Conventionally, X-ray is performed in the upright position with antero-posterior and latero-lateral projection, often associated with dynamic flexion–extension study to evaluate vertebral stability.

Computed tomography (CT)

CT is considered the gold standard imaging technique to perform accurate evaluation of bone detail and implant position. Its crucial clinical application is represented by the evaluation of the effects of fusion surgery and in case of stenosis of the vertebral canal. Modern multi-row detector

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scanners allow to perform studies with very low collimation, high spatial resolution and effective multiplanar reconstructions. CT is now playing a much more prominent role in the evaluation of pre- and post-operative spine thanks to a decreased amount of radiation exposure as well as better spatial and contrast resolution and a larger field of view [17, 18]. Acquisitions are made on axial plane with thickness inferior to 1 mm (0.625). Workstation multiplanar reconstructions (MPRs) in sagittal and coronal plane and volume rendering (VR) are useful to visualize the spatial position of the spinal devices. It is possible, however, to demonstrate the presence of osteolysis related to polyethylene wear and fluid collections; in addiction, it is useful to evaluate foreign body soft tissue reactions and subtle fractures [19–22]. It is possible to perform intraoperative 3D scans after pedicle screw positioning which allows avoiding false placement and primary neurovascular damages. Immediate correction of misplaced screws decreases the secondary revision rate and prevents secondary neurovascular problems, instability or dislocation of the fixator. To reduce the presence of artefacts due to metallic devices, special projections (perpendicular to the orthopaedic implant), appropriate imaging algorithms (high peak voltage, high tube current, narrow collimation) and reconstruction (use of thick sections, lower kernel values) can be used [23–25]. The use of CT myelography is required in patients with contraindications to MRI in order to evaluate the nerve roots and spinal canal in relation to post-operative infection, adjacent segment degeneration, hardware impingement and post-operative fibrosis [26, 27]. In fact, CT myelography needs a lumbar puncture with contrast administration and is associated with risks of epidural injection, infection, contrast allergy and bleeding [28, 29]. However, CT myelography remains the modality of choice for localizing a post-operative CSF leak [30–32]. It has been shown that it is able to more accurately define the degree of spinal and neural foraminal stenosis compared with MRI [33]. MRI assists in the characterization of fluid collections and of the extent of infection and identification of possible epidural communication.

Magnetic resonance imaging (MRI)

MRI is the method of choice each time a recurrence of pain is perceived after surgery, because it is more accurate respect to CT in the evaluation of soft tissue involvement described by contrast enhancement which best depicts differences between recurrence of disc herniation versus post-surgical epidural fibrosis, bone marrow oedema and in documenting and monitoring complications such as soft tissue and joint inflammation, hemorrhage, spinal stenosis [34, 35]. More recent surgical materials (i.e., titanium) considered these aspects and are now less prone to produce metallic artefacts in MRI sequences. Some sequences, like spin-echo (SE) and gradient-echo (GE), should be avoided in patients with metallic implants of spine, because much more sensitive to susceptibility artefacts.

Finally, some low magnetic field systems allow upright study of the cervical and lumbar spine, which can usefully evaluate efficacy of surgical treatments of vertebral instability. MRI is also used for determining integration of nucleus disc replacement. In the presence of metallic hardware, MR images can be optimized by increasing bandwidth, using spin-echo and turbo spin-echo sequences rather than gradient-echo sequences, and by reducing TE to increase the signal-to-noise ratio and minimize magnetic susceptibility artefact. The metal artefact reduction sequence is another means of optimizing images. In this sequence, the section-selection gradient and bandwidth are increased with a narrow slice thickness and increased read gradient, and the view angle tilting is used [36]. Open MRI systems, low- and medium-intensity magnetic field allows a study even in the upright position especially to assess the amplitude of the spinal canal in a more physiological state or by using axial loading either by flexion–extension [37, 38]. It was shown that the space within the canal is posture dependent because there is a significant reduction in spine cross-sectional area during axial loading resulting in increased diagnostic specificity of the spinal stenosis. It is possible to document also spondylolisthesis and radicular conflicts, not detectable with a static study [39]. In post-operative intervertebral discs imaging it is possible to detect normal findings and complications. Different imaging methods can be proposed for the various purposes of post-operative spine imaging; nevertheless, the aim of this paper to focus on intervertebral disc pathology. In this category of patients, MR is the gold standard imaging method in both pre- and post-surgical evaluation.

In cases treated with open micro-invasive surgery, bone and paraspinal tissue changes are related to the type of surgical procedure that ranges from hemi-laminectomy characterized by total or partial resection of the lamina and ligamentum flavum to less invasive microsurgical approaches where it is often difficult to recognize, especially after a long time, the signs of surgery. Interpretation of images of post-operative spine in the immediate post-operative period, i.e., the first 6–38 post-surgical weeks, must be undertaken with caution. Normal, or at least expected, post-operative changes occur within the bones as well as the soft tissues and vary in part depending on the type and extent of surgery and the time since the operation [40, 41]. Foreign ferromagnetic metal objects such as spinal fixation devices give rise to local distortion of the magnetic field. This metal artefact is explained by the occurrence of a local gradient, which is non-negligible compared with the frequency-encoding gradient. When the implants are made of materials, which are not superparamagnetic, such as titanium or tantalum, distortion of the magnetic field is less severe, but these materials may still obscure normal regional anatomy. To perform diagnostic images, a rigorous technical approach is very important [41]. The knowledge of chirurgical approach and devices is also useful to interpretation of MR results.

Both sagittal and axial images have to be obtained in the post-operative spine MR control. On the sagittal plane, T1- and T2-weighted images and, on axial plane, SE T1-weighted images before and after intravenous administration of gadolinium contrast medium are the routine basic protocol. The enhancement pattern of nerves, meninges, zygo-apophyseal joints and paraspinal soft tissues must be evaluated. In the lumbar spine, additional contrast-enhanced T1-weighted images with fat suppression technique can be used to differentiate enhancing scar from epidural fat. However, abnormal post-operative nerve root enhancement may be more difficult to differentiate from the normal slight pial-root enhancement usually seen on fat-suppressed images. In rare cases, fat suppression can be helpful for distinguishing between post-operative blood and normal epidural fat. The presence of metallic implants is not a contraindication to MRI [42] but they can create severe magnetic susceptibility artefacts when superparamagnetic materials such as steel are used. In this case, FSE sequences must be preferred to conventional SE sequences and gradient-echo acquisitions because they have less magnetic susceptibility. In the presence of metals, which are not super paramagnetic, such as titanium, the artefacts produced influence primarily the radiofrequency, with less marked artefacts [43]. Although 3D-TSE sequences have been suggested, the acquisition time significantly adds to the overall duration of the examination.

Normal post-operative findings

Intervertebral disc, however, can sometimes appear hypointense on T1 and hyperintense on T2 with associated disruption of the annulus fibrosus; 80% of cases can also show contrast enhancement (CE). This finding, named “mechanical or chemical discitis”, disappears after 4–5 weeks and is not associated with positive inflammation indices [1]. Rarely after discectomy may occur moderate irregularities of vertebrae profiles with hypointensity in T1, hyperintensity in T2 and CE of subchondral spongiosa, in relation to bone marrow oedema (Fig. 1). This is an occurrence without pathological significance (aseptic spondylodiscitis), which disappears in a few weeks.

Imaging of post-operative disc complications

In the 2 months after discectomy, persistence of symptoms arising from compression on roots and dural sac can be related to residual or recurrent hernia or/and exuberant scar [19]. Differential diagnosis between them is difficult as a result of the frequent coexistence of both. It is necessary to exactly known anatomy and the different semiological aspects such as mass effect, dural traction, impression on the dural sac, relations with the disc, pattern of contrast enhancement especially immediately after surgery [44].

Recurrence of disc herniation

Usually herniated disc causes mass effect with compression on the antero-lateral dural sac without dural traction and with a clear continuity with the disc (Fig. 2). There is no early CE for pathological lack of vascularization; sometimes can be found early peripheral contrast enhancement with delayed (10 min) central diffusion due to the presence of granulation tissue; in a later phase (1 month), CE can occur for a diffusion mechanism.

Exuberant surgical scar

In surgical scar, in early stage, there is not mass effect, but there is dural traction and contiguity with the disc. Exuberant scar tissue surrounds generally the dural sac (especially along the surgical edges) with possible compression mechanism. Contrast enhancement is early, intense and diffused thanks to neo-angiogenesis and then trends to significantly disappear at least after 1 year [45]. Therefore, important for differential diagnosis is CE MR images acquired within 7–10 min.

Post-surgery complications are mainly infectious such as radiculitis, discitis, spondylitis, spondylodiscitis, arachnoidal inflammation. Despite current prophylactic measures, surgical site infections (SSIs) rates have been reported in up to 15% of patients undergoing spine surgery [46]. Predictors of post-surgical morbidity and mortality associated with epidural abscess were identified recently by Schoenfeld and Wahlquist [47] in a Nationwide Inpatient Sample (NIS) from 2006 to 2011. They conclude that age, insurance status, paralysis and medical comorbidities appear to be the predictors of morbidity and mortality in trauma patients submitted to surgical treatment. Moreover, early recognition of infections, haematomas and abscesses is essential to make an appropriate treatment and thus minimize the effects. MRI represents the modality of choice in detecting spinal infection thanks to high sensibility and specificity of the sequences performed before and after gadolinium administration.

Fig. 1 MRI—**a** T2-weighted (T2-w), **b** T2-w fat saturated and **c** T1-w on sagittal plane. Control after neurosurgical intervention for disc herniation on L4–L5. MR shows evident reduction in height of the L4–L5 disc, associated with slight bone marrow oedema of the vertebral endplates

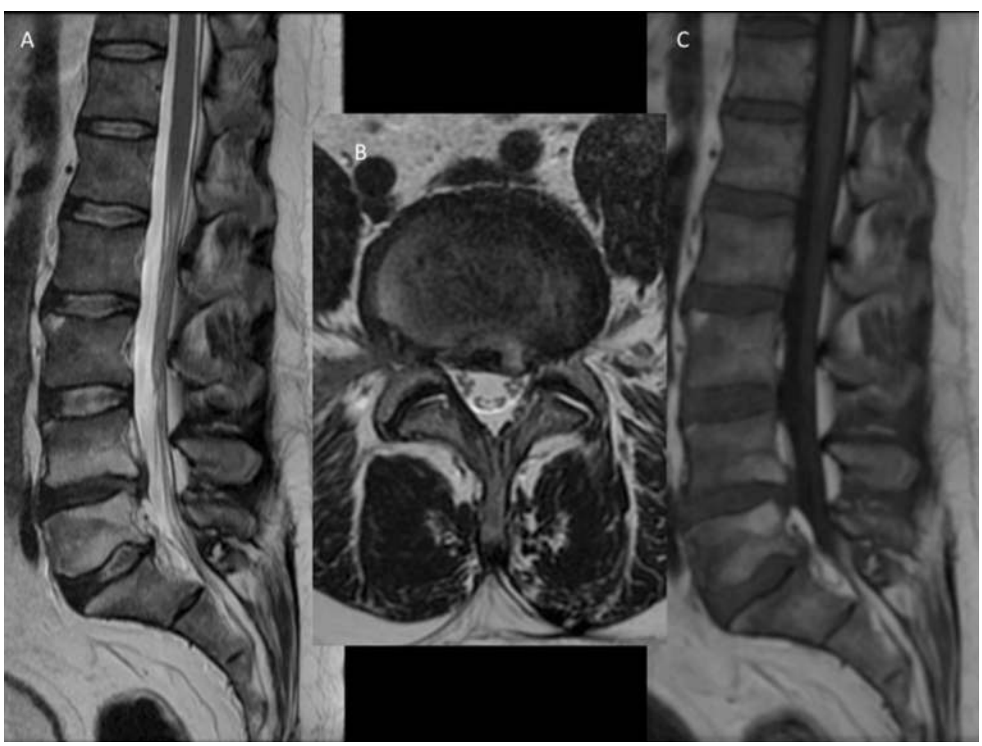

Fig. 2 MRI—**a** T2-w on sagittal plane, **b** T2-w on axial plane and **c** T1-w on sagittal plane. Recurrence of disc herniation after neurosurgical intervention. MR shows dehydration of the L4–L5 intervertebral disc, associated with left disc herniation on the same level. Bone marrow oedema of the L4 and L5 endplates is also evident

Radiculitis

It is characterized by pathological CE of the roots, secondary to temporary damage of themselves barrier caused by surgery or chronic trauma of slipped disc before surgery [48–50]. If there is a radicular infection, pathological contrast enhancement (CE) of the roots is easily demonstrated by post-contrast fat sat T1 sequences [33]. Contrast enhancement of the intrathecal spinal nerve roots of the cauda equina following a conventional dose of 0.1 mmol/kg gadolinium contrast medium is not normal. The time of MRI follow-up is very important, in fact an early roots CE secondary to temporary damage of blood-nerve barrier is caused by surgery. In the presence of clinical infection suspicion, the MR images should be considered pathological if documented CE after 6 months. In one study, intrathecal nerve root enhancement was seen in 20% of patients who were asymptomatic 6 weeks after disc surgery, but in only 2% after 6 months [44]. This finding should be considered pathological if documented after 6 months, as before, although present and asymptomatic, is not pathological because is a part of the regular post-surgery evolution.

Infectious complications

Infectious complications (discitis, spondylitis, spondylodiscitis) are appreciable at short time after surgery, characterized by the appearance after healthy little period of persistent and progressive low back pain associated with inflammatory markers increase (fever, elevated CRP) (Figs. 3, 4, 5, 6) [51]. MR shows signal alteration of the disc and subchondral bone (T1 hypointensity, T2–T2 STIR hyperintensity). There is CE with possible and pathological involvement of paravertebral surrounding soft tissues and spine canal with impression on root and dural sac. Risk factors can be related to the nature of the spinal pathology and the surgical procedure such as extensive soft tissue dissection, longer operating time, soft tissue devitalisation, kind of surgical instrumentation and systemic health conditions. Abscess, alone or in association with discitis or osteitis, is characterized by a collection that extends from the disc to the epidural space. It is characterized by T2 hyperintensity with irregular peripheral rim CE. This complication, although rare, may occur 2–4 weeks after surgery and may become a possible cause of new neurological deficits requiring urgent decompression.

Meningeal inflammatory reactions

In a study of symptomatic patients, contrast enhancement of spinal nerve roots was demonstrated at the surgical site, and extending cranial and caudal, in the chronic post-operative period, more than 6–8 months after surgery [52]. Arachnoidal inflammation is not common (6–16% of surgery), especially in opening or fissuring of the dural sac. The potential factors inciting chronic sterile spinal arachnoiditis are much debated but include the surgical procedure itself, the presence of intradural blood following surgery, diagnostic lumbar puncture, treated perioperative spinal infection, the previous use of myelographic contrast media (especially older oil-based preparations) and prior intraspinal injection of anaesthetic, anti-inflammatory or chemotherapeutic agents (e.g., steroids, methotrexate) [49]. The three MR patterns in adhesive arachnoiditis are scattered groups of matted or clamped nerve roots, empty thecal sac caused by adhesion of the nerve roots to its walls and intrathecal soft tissue mass with a broad dural base, representing a large group of matted roots that may obstruct the cerebrospinal fluid pathways [53]. Moreover, there is low CE of cauda roots. The symptoms, not always present, usually indicate involvement of multiple roots, with pain and paresthesia being perceived in both legs. For these reasons, the knowledge of clinical and laboratory data is mandatory for diagnostic evaluation.

Other

Less frequent complication is CSF fistula (Fig. 7), haematoma, seroma, meningoceles, pseudo-meningoceles.

Imaging of intradiscal O2–O3 discolysis

Oxygen–ozone discolysis is a well-know non-invasive, conservative and alternative treatment proposed for disc herniation; it is meant to produce disc shrinkage through dehydrating and creating a vacuum inside the disc itself. Short, calculated oxidative stress achieved by ozone administration is reported to be able to correct permanent imbalance caused by excessive or chronic oxidative injury [54–56].

The procedure performed by expert interventional neuroradiologist can be easily and safely performed under CT guidance and with i.v. antibiotic administration prior to perform the injection. The immediate control, after intradiscal O2–O3 mixture injection, will show gaseous coefficients inside the disc and around the meningeal layers in the epidural space. A recently published paper produced by our group showed how diffusion weighted imaging is able to predict shrinkage of the treated disc, by analysing T2 "shine-through" effects on DWI/ADC maps (Fig. 8) which is present in those patients which will show later on, appearance of vacuolar degeneration of the disc, with reduction/disappearance of the herniated volume [57–59].

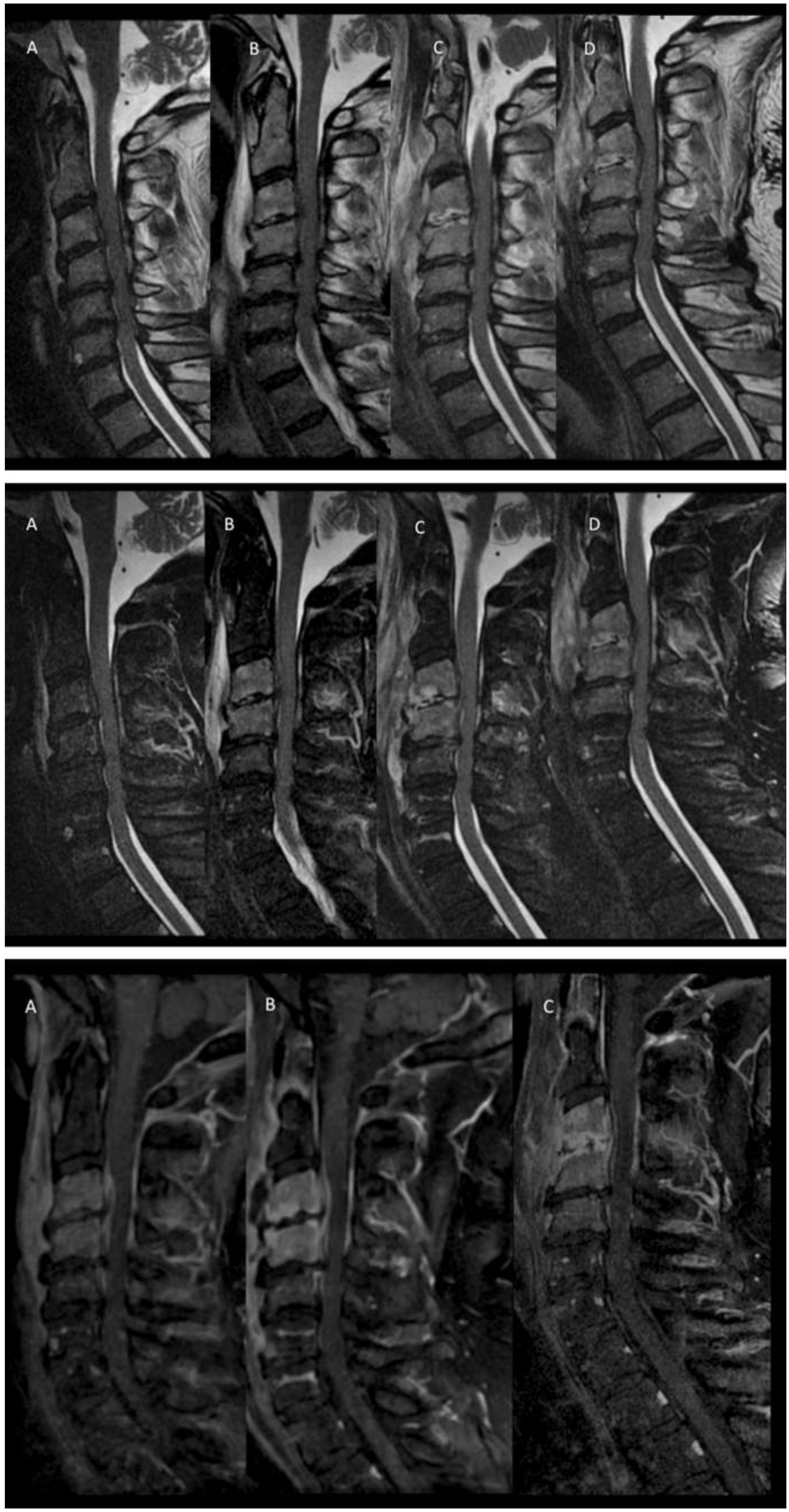

Fig. 3–5 MRI (3 **a–d** T2-w, sagittal plane)—(4 **a–d** T2-w fat sat, sagittal plane)—(5 **a–c** T1-w with CE, sagittal plane). MR shows consecutive examinations on a patient affected by stenosis of the vertebral canal of the cervical tract before and after surgical treatment, complicated by C3–C4 spondylodiscitis. Since first post-operative examination (3**b**, 4**b**, 5**a**) altered MR signal intensity is shown at C3–C4 level, with progressive involvement of the disc. Increasing bone marrow oedema and contrast enhancement are also shown during a period of 6 months

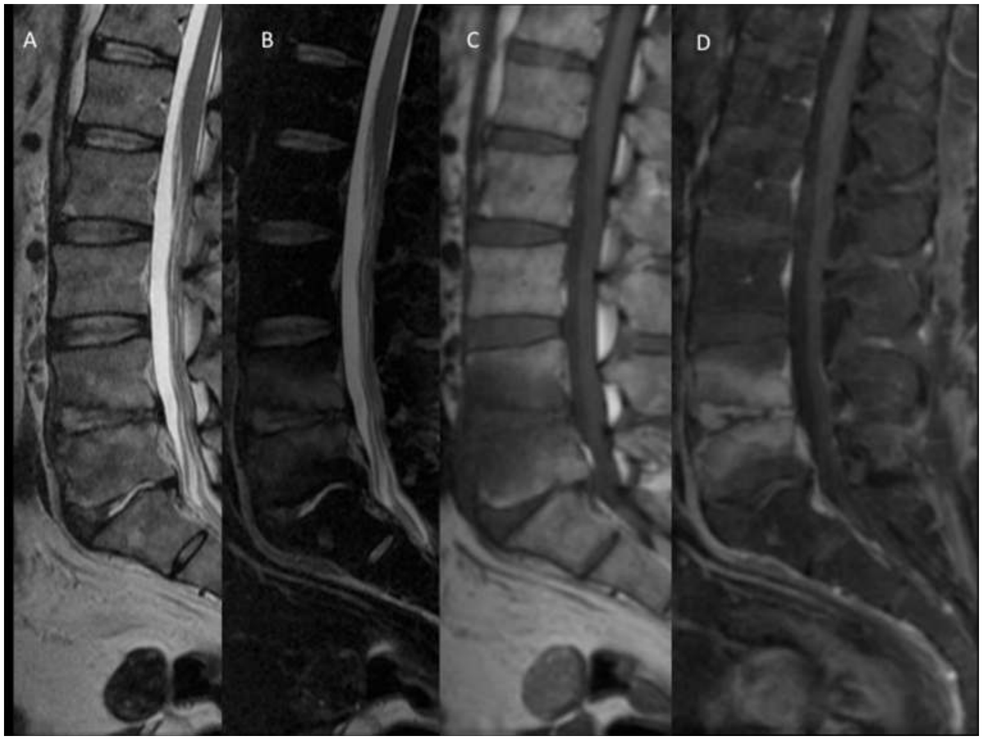

Fig. 6 MR (**a** T2-w/ **b** T2-w fat sat/ **c** T1-w/ **d** T1-w + CE, sagittal plane) shows post-surgery examination of a patient who underwent surgical intervention for L4–L5 disc herniation with infectious complications. Evident bone marrow oedema of the corresponding vertebral endplates, increased signal of the disc, associated with diffuse contrast enhancement of both bone and disc demonstrates spondylodiscitis at the same level

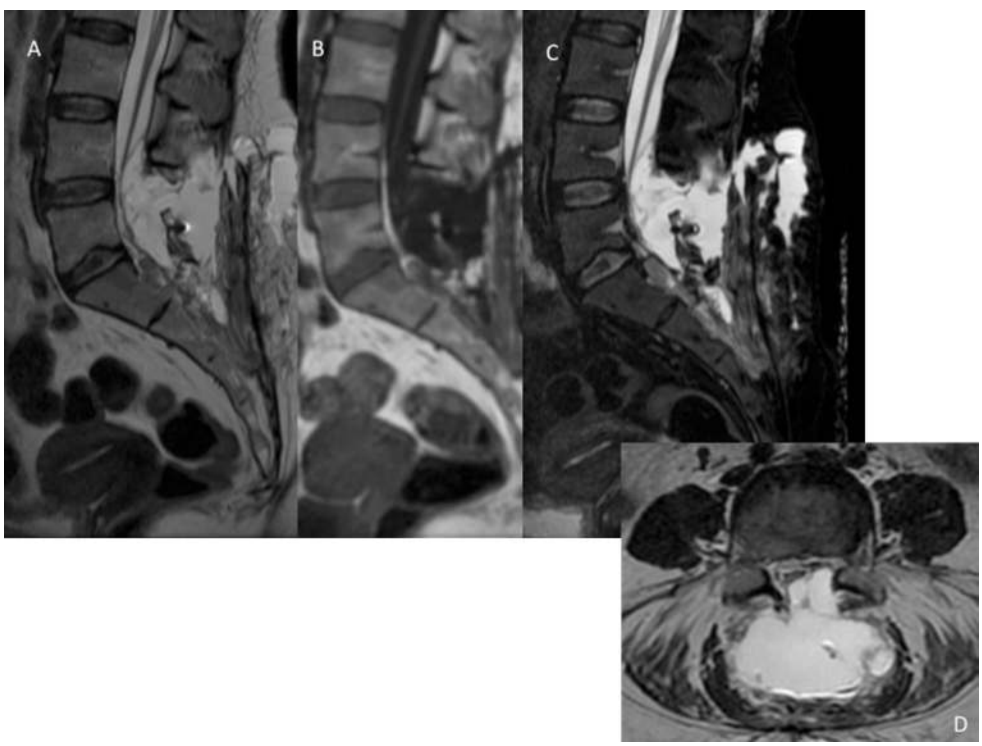

Fig. 7 (**a** T2-w/ **b** T1-w/ **c** T2-w fat sat, sagittal plane/ **d**: T2-w, axial plane) MR shows lumbar post-surgical CSF fistula, with extensive collection of CSF in the paravertebral soft tissues, associated with disruption of the posterior vertebral arches of the L4–S1 spinal tract

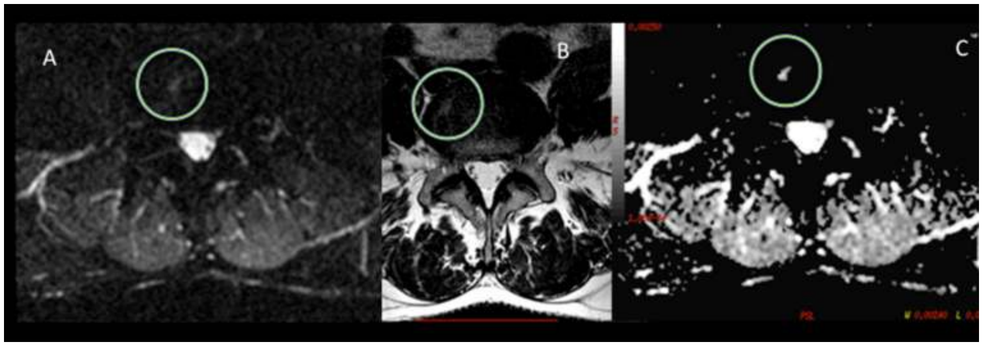

Fig. 8 (**a** DWI/ **b** T2-w/ **c** ADC map, axial plane) T2 "shine-through" effect (*green circle*) in the right antero-lateral aspect of this L4–L5 intervertebral disc, 2 months after O2–O3 discolysis

Conclusion

It is important to know imaging technique indications and limits, to choose what of these will give the best information about the status of spine in post-operative follow-up. Radiologists must be able to understand the normal imaging appearances and unique complications of instrumentation and surgical or non-surgical approaches.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical standards For this type of article, formal consent from a local ethics committee is not required.

Informed consent Informed consent was obtained from all patients before diagnostic examination.

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