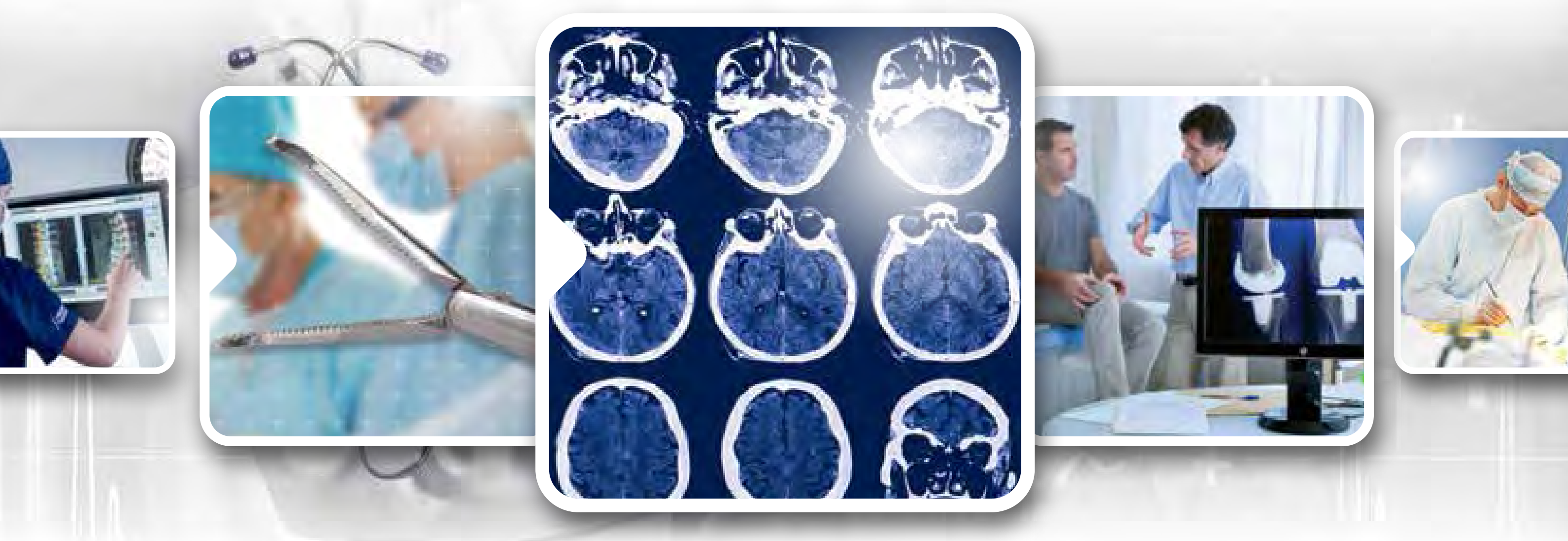
ab medica®
about people about health



neuroradiology **solutions**

www.abmedica.it

ab medica s.p.a.
Via nerviano, 31 - 20020 Lainate (MI)
tel +39 02 933051 - fax +39 02 93305400
abmedica@abmedica.it

Original article

NRJ

The Neuroradiology Journal
2015, Vol. 28(3) 341–346

DOI: 10.1177/1971400915594508
neu.sagepub.com
SAGE

Does evaluator experience have an impact on the diagnosis of lumbar spine instability in dynamic MRI? Interobserver agreement study

Lucia Patriarca[1], Mayla Letteriello[1], Ernesto Di Cesare[1], Antonio Barile[1], Massimo Gallucci[2] and Alessandra Splendiani[2]

Abstract

Objectives: We aimed to evaluate interobserver agreement in the definition of spine instability among spine neuroradiologists with or without experience in dynamic magnetic resonance imaging (MRI).

Material and methods: Two expert neuroradiologists and two residents retrospectively evaluated the pre-operative dynamic MRI examinations of patients with vertebral instability. Segmental motion, defined as excessive (more than 3 mm) translational motion from supine to upright, was investigated in 103 subjects (309 segments) using kinetic MRI. Radiographic parameters which can help indicate segmental instability include disc degeneration, facet joint osteoarthritis, and ligament flavum hypertrophy. These three radiographic parameters were simultaneously evaluated, and the combinations corresponding to significant segmental instability at each level were determined. The agreement among the neuroradiologists was calculated using the kappa coefficient. All patients had neurosurgical intervention to stabilize the spine.

Results: Agreement was high among experienced and non-experienced neuroradiologists. Agreement was nearly perfect for spinal location of spinal instability.

Conclusions: This study demonstrates that the experience of the evaluator has a low impact on the assessment of spinal instability if correct classification is used. The interobserver agreement confirms the usefulness and safety of kinetic MRI in the correct diagnosis of spinal instability even by less experienced evaluators.

Keywords

instability, observer variation, lumbar spine, dynamic MR

Introduction

According to the American Academy of Orthopaedic Surgeons, instability is defined as an abnormal response to applied loads, characterized by movement in the motion segment beyond normal constraints.[1] Segmental instability has been defined as occurring in patients with low back problems whose clinical status is unstable, with symptoms fluctuating between mild and severe in response to even minor provocations. Frymoyer et al. defined segmental instability as "a condition where there is loss of spinal stiffness, such that normally tolerated external loads will result in pain".[1] Clinical criteria for lumbar spine instability have not been clearly defined, yet. A loss of tone in the legs or in the low back and pelvic region (i.e. giving away phenomenon) has also been observed in some patients with lumbar instability. However, these clinical criteria have not been rigorously evaluated.[2,3]

Overall, the relationship between imaging instability and its symptoms is controversial. Pitkanen et al.[4] found poor correlation between clinical signs of lumbar instability and abnormalities found on functional radiographs. Dvorak et al.[5] found that the analysis of the segmental motion of the lumbar spine using functional radiographs does not aid in differentiating the underlying pathological condition of a patient with low back pain. Conversely, Fujiwara et al., measuring sagittal translation and rotation at the L4–5 segment in flexion–extension radiographs, showed that patients with 3 mm or greater translation had been suffering from low back and/or leg pain the longest, and had significantly lower scores than patients with less than 3 mm translation.[6] Magnetic resonance imaging (MRI) is generally considered to be the most valuable

[1]Department of Applied Clinical Sciences and Biotechnology, Radiology Unit, University of L'Aquila, L'Aquila, Italy
[2]Department of Applied Clinical Sciences and Biotechnology, Neuroradiology Unit, University of L'Aquila, L'Aquila, Italy

Corresponding author:
Alessandra Splendiani, Department of Applied Clinical Sciences and Biotechnology, University of L'Aquila, Via Vetoio, 67100 L'Aquila, Italy.
Email: alessandra.splendiani@cc.univaq.it

method to diagnose degenerative abnormalities of the spine, except for the vacuum phenomenon, and it is often considered the most useful modality for evaluation of myelopathy, radiculopathy, and low back pain requiring advance imaging.[7,8] Many authors studies have documented that a high percentage of asymptomatic patients have abnormal findings on imaging studies for disc degeneration (DD).[9] Dynamic MRI allows to visualize both dynamic and abnormal segmental motion.[10–13]

Materials and method

For this study, 103 patients who had undergone surgical intervention for spine instability and who had been submitted for pre-surgical dynamic MRI study (low-field MRI G-Scan, Esaote, Italy) were retrospectively re-evaluated by two expert neuroradiologists and two residents. There were 48 males and 55 females. The mean age was 42.1 (range 16–85 years).

In each patient DD, facet joint osteoarthritis (FJO), and ligament flavum hypertrophy (LFH) at L3–L4, L4–L5, and L5–S1 were evaluated (309 lumbar segments). Varying combinations of these parameters were analysed in an attempt to find more reliable indications for segmental instability. DD was classified into one of five grades using the Pfirrmann criteria. Grade I corresponded to normal discs and Grade V corresponded to advanced degeneration. FJO was classified into four grades according to Fujiwara et al.'s method.[6] Grade 1 corresponded to normal facet joints; grade 2, 3, 4, to mild, moderate, severe facet joint degeneration, respectively. LFH was classified as being either negative or positive. Negative classification corresponded to having no LFH, and positive classification indicated the presence of LFH.

Segmental motion was determined to be the difference in displacement between supine and upright MRI study. Segmental instability was defined as excessive segmental motion (more than 3 mm translation) (Figure 1).

The incidence of segmental instability according to age and gender was analysed using the Chi-square test and student *t*-test, respectively. Relationships between radiographic parameters and segmental instability at L3–L4, L4–L5 and L5 S1 were analysed using the Chi-square test. The criterion for statistical significance was $p < 0.05$.

Short standard protocol included sagittal T1 and T2 weighted sequences and axial T2 for all patients.

The interobserver agreement for the final instability score among the participants was calculated according to the kappa coefficient and the percentage of agreement. The reliability was evaluated as proposed by Landis and Koch[13]: 0–0.2 indicated poor agreement; 0.21–0.4 indicated fair agreement; 0.41–0.6 indicated moderate agreement; 0.61–0.8 indicated substantial agreement; and 0.81–1.0 indicated very good agreement.

Results

The interobserver agreement in this study between two expert neuroradiologists (more than 20 years experience) was nearly perfect (Table 1). The agreement between the two residents (3 years experience) was

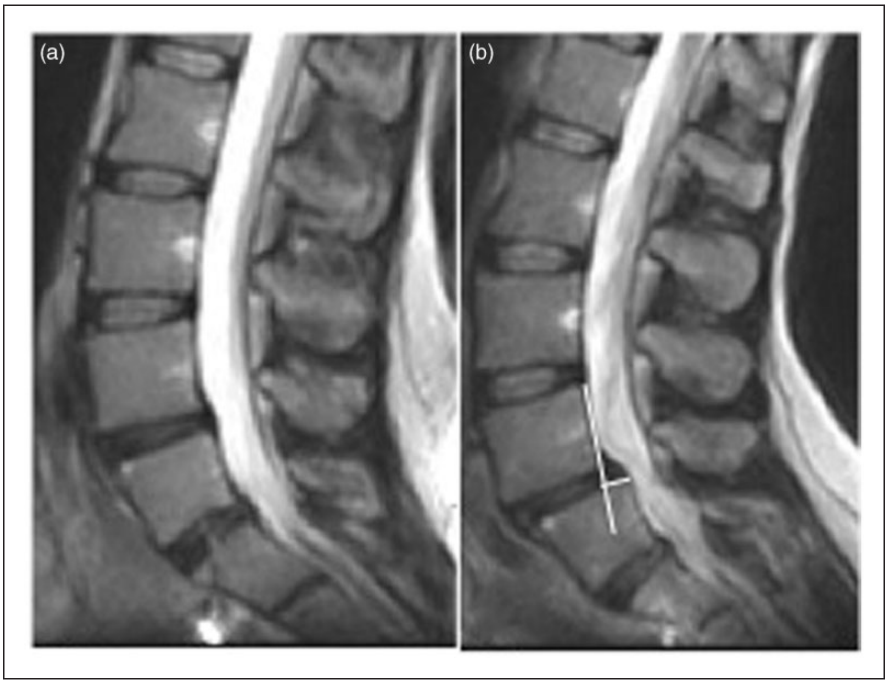


Figure 1. A 55-year-old man with low back pain. (A) Sagittal T2-weighted image of lumbar spine shows dehydration of nucleus pulposus of L5–S1. (B) In upright position there is a spondylolisthesis in the L5–S1 >3 mm.

Table 1. Agreement between experienced radiologists. Disc degeneration (DD), facet joint osteoarthritis (FJO), and ligament flavum hypertrophy (LFH).

	% of overall agreement	Fixed-marginal kappa	Agreement
DD	86.67%	0.76985	Substantial
FJO	89.78%	0.92457	Near perfect
LFH	93.76%	0.89598	Near perfect

Table 2. Agreement between residents. Disc degeneration (DD), facet joint osteoarthritis (FJO), and ligament flavum hypertrophy (LFH).

	% of overall agreement	Fixed-marginal kappa	Agreement
DD	83.65%	0.6756	Substantial
FJO	71.34%	0.5798	Moderate
LFH	61.29%	0.3563	Fair

Table 3. Agreement between all in low-grade of instability. Disc degeneration (DD), facet joint osteoarthritis (FJO), and ligament flavum hypertrophy (LFH).

	% of overall agreement	Fixed-marginal kappa	Agreement
DD grade1	89.84%	0.749	Substantial
FJO grade1	86.66%	0.6676	Substantial
LFH absent	75.34%	0.6554	Moderate

Table 4. Agreement between all in high-grade instability. Disc degeneration (DD), facet joint osteoarthritis (FJO), and ligament flavum hypertrophy (LFH).

	% of overall agreement	Fixed-marginal kappa	Agreement
DD grade5	87.56%	0.776	Moderate
FJO grade4	76.76%	0.7137	Moderate
LFH present	55.99%	0.3233	Fair

fair to substantial (Table 2). In the present study, agreement in the results of the instability score when considering all examiners was substantial.

However, agreement between the residents was substantial when the evaluation was performed for low-grade instability (DD grade 1, FJO grade 1 without LFH), and moderate and fair in the case of high-grade instability (DD grade 5, FJO grade 4 with LFH) (Tables 3 and 4).

Discussion

Instability can be considered as part of the normal degenerative process of the lumbar spine, which has three phases. Initially, there is abnormal motion of the spinal segment (disc, adjacent vertebrae, ligaments, facet joints) and pathological signs of degeneration are minimal; this stage is termed ‘‘spinal dysfunction’’. The signs of relative spinal motion (e.g. translation and sagittal rotation of the vertebral bodies with respect to each other) can be uncovered with upright/positional MRI.

During the second or ‘‘instability phase’’, signs of degeneration are more prominent and there is increased and abnormal intersegmental movement. Instability can be demonstrated as relative hypermobility at the spinal motion segment compared with adjacent motion segments on positional MRI (Figure 2). Excess extension can in turn increase the degree of foraminal, central, and lateral recess stenosis, which may correlate with increased levels of pain. Instability of a degenerative or isthmic spondylolisthesis nature can increase central or foramina stenosis. The disc below a degenerate spinal level can be susceptible to degeneration and disk herniation changes in size under physiological load. As degeneration progresses, fibrosis and osteophytosis result in restabilization and consequential reduction in movement (third phase). This ‘‘restabilization phase’’ can be difficult to distinguish from the instability phase without positional imaging – an important consideration if surgery is being contemplated. How often and when this distinction needs to be made remains to be determined. Most degenerative and isthmic spondylolisthesis appear stable, with no significant positional change in either angular rotation or horizontal translation.[14]

The association of vertebral instability with changes in the bone marrow adjacent to the endplates has been discussed, but without consistent results. Modic et al.[15] stated that the clinical importance of these changes in the bone marrow is unknown. Lang et al.[16] observed bone marrow changes adjacent to the endplates in postoperative instability, but no statistically significant correlation exists between segmental instability and abnormalities of the bone marrow adjacent to the endplates in patients without spinal fusion, as seen in a study by Bram et al.[17] Conversely, Bram et al. found a significant association between radiographic instability and traction spurs, and between radiographic instability and annular tears.[17] In their study of patients with chronic low back pain, Aprill and Bogduk[18] first described annular tears as a high signal intensity dot on sagittal T2-weighted images.[19,20] Therefore, flexion–extension radiographs should be considered in patients with annular tears or traction spurs. However, additional studies supporting this conclusion are necessary before it can be generally accepted. A high signal intensity zone in the posterior annulus fibrosus on sagittal T2-weighted images has been found much too frequently in asymptomatic subjects to be considered a reliable independent diagnostic indicator.

Spondylolisthesis is anterior or posterior displacement (translation) of a vertebra relative to an adjacent vertebra. Anterolisthesis refers to anterior displacement

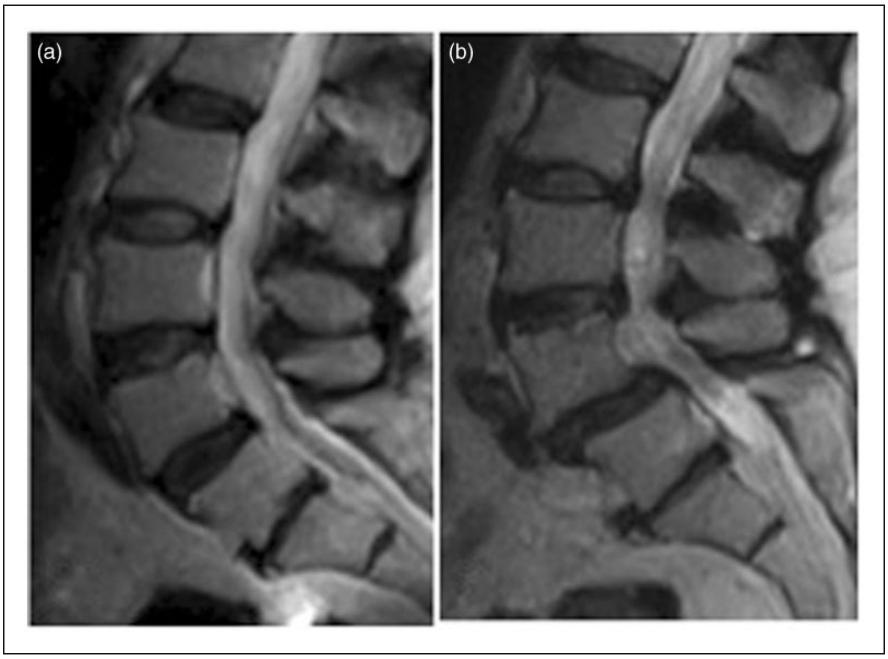


Figure 2. A 75-year-old woman with neurogenic claudication. (A) MR examination in recumbent position shows mild listhesis of L5 and diffuse degenerative phenomena. (B) In the upright examination the shifting of the vertebral body >3 mm is evident.

of a vertebra relative to the adjacent caudal (inferior) vertebra, while retrolisthesis refers to posterior displacement. Severity is graded by the percentage of the vertebral body that is displaced (Grade I–IV).[21,22] Spondylolisthesis frequently causes neural foraminal narrowing, best evaluated on sagittal T1-weighted MRI.[23] The normal shape of the neural foramen is altered; the longest axis of the foramen changes from vertical to horizontal. Sagittal MRI can demonstrate foraminal stenosis, obliteration of foraminal fat, and nerve root compression and/or kinking. A fibrocartilaginous mass may be seen around the non-healed pars fracture. A disc herniation is more common at the level above the spondylolisthesis than at the same level. The anterior displacement of the upper vertebra relative to the disc confers the artifactual appearance of a disc bulge or herniation (pseudo-bulge or herniation). Degenerative spondylolisthesis appears to be associated with instability or hypermobility when studied with kinematic MRI. Degenerative disk disease and FJO affect the stability of the motion segment.[24] However, the exact relationship between degenerative disk disease, FJO, and vertebral instability at MRI has not been defined. Murata et al. compared disk degeneration at MRI with that at flexion–extension radiography and found no statistically significant relation between segmental instability and disk degeneration.[25,26]

No study, to our knowledge, has investigated the effect of induced disk degeneration.[27,28] Fujiwara et al.[2] compared MRI and functional radiography of the lumbar spine to examine the relationship among segmental instability, disk degeneration, and FJO in patients with low back pain; they reported that an anterior translation of 3 mm or greater was positively associated with DD and FJO. Recently Splendiani et al. reported a study that suggests that the pathogenesis of radicular pain in some patients is the result of a dynamic stenosis of the foramen caused by the physiological load.[11] In fact, they demonstrated that the association between disk pathology and facet osteoarthritis can determine foraminal occult stenosis.

Imaging with the patient in a supine position may not correctly represent the degree and the clinical relevance of a foraminal stenosis.[11] Although the lumbar spine undergoes large compression loads in normal activities, MRI is routinely performed with the patients supine and, therefore, with the spine unloaded. Advances in MR techniques have made possible the development of open MRI systems, which provide the opportunity to investigate spinal kinematics and vertebral instability. Early studies were limited to assessing spinal kinematics by imaging the patient in the supine position in combination with several different axial loading MRI-compatible devices, and did not truly reflect postural spinal changes related to muscle tone, loads on the lumbar spine that increase in a caudal direction rather than being uniform at each spinal level, and the effects of core muscle activation on the spine. Improvements in available open MRI systems from increased field strength, field homogeneity, gradient generation, coil technology (quadrature coils), and faster image acquisition (dynamic equilibrium and magnetization transfer) have resulted in better signal-to-noise ratios, contrast and spatial resolution and, therefore, image quality. Open MRI systems with a vertical gap allow imaging under the influence of gravity in the upright position (seated or standing), with varying kinetic manoeuvres (flexion, extension, lateral bending, rotation, etc), as well as with the patient supine. Imaging in the physiologically representative upright position and with kinetic manoeuvres allows accurate assessment and measurement of changes in the relationship between the components of the functional spinal unit and the potential to correlate radiological signs with positional symptoms. On supine imaging, spinal alignment does not reflect the true postural effect of body weight, which can increase by 80%, and the action of paraspinal and abdominal musculature. Imaging in the supine position and with non-dynamic methods can only identify indirect radiological signs of instability (i.e. degenerative changes of the disc, ligaments, and facet joints), and some direct signs (malalignment of the vertebral bodies). Upright and positional MRI can demonstrate changes in intersegmental motion that may correlate with clinical symptoms of low back pain and neurogenic claudication. As yet, however, no published studies have dealt with this topic.[29]

There are several limitations to this study. This is a retrospective study, therefore we enrolled only patients who underwent surgical spine intervention for instability in order to validate the test; we hope in the future to extend the study to all patients with low back pain in order to investigate the diagnostic performance of kinetic MRI in detecting lumbar instability. Moreover, our kinetic MRI equipment uses a 0.25 T magnetic field, in contrast to conventional high-field MRI study of the spine.

Although the lower field strength of the system results in a reduced signal-to-noise ratio, and thus, overall reduced image quality compared with high-field magnets, we have found that image quality is certainly adequate for the demonstration of lumbar canal stenosis and nerve root compression. Finally, the availability of these imaging techniques is nowadays restricted to a few centres.

Conclusions

Our study demonstrates that advanced neuroradiological imaging techniques have improved our ability to localize the site of nerve root entrapment in patients presenting with low back pain or painful radiculopathy, also when referring physicians are not experienced. Although conservative medical management may be successful,[30] surgical decompression by wide laminectomy or an intralaminar approach should be done in patients with serious or progressive pain or neurological dysfunction. More recently, a percutaneous minimally invasive approach has been proposed.[31] Therefore, since the early diagnosis and treatment of foraminal stenosis may prevent intractable pain and permanent neurological sequelae, a dedicated MR unit able to perform orthostatic studies can be useful to achieve the correct diagnosis. Conventional high-field MRI with the patient in the supine position is now widely available, and remains the technique of choice for the investigation of degenerative lumbar spine disorders associated with lower limb symptoms. However, there is no doubt that clinically relevant spinal canal stenosis can be uncovered by imaging in the erect position. In cases where conventional MRI shows no evidence of cauda equina or lumbar nerve root compression in the setting of convincing clinical symptoms that warrant surgical intervention, reimaging in the upright position, with the addition of flexion and extension, is recommended.

Funding

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

Conflict of interest

None declared.

References

1. Frymoyer JW, Akeson W, Brandt K, et al. *New perspectives on low back pain*. Rosemont, Ill: American Academy of Orthopaedic Surgeons, 1989, pp.217–248.
2. Fujiwara A, Lim T, An H, et al. The effect of disc degeneration and facet joint osteoarthritis on the segmental flexibility of the lumbar spine. *Spine* 2000; 25: 3036–3044.
3. Panjabi MM and White AA III. Basic biomechanics of the spine. *Neurosurgery* 1980; 7: 76–93.
4. Pitkänen MT1, Manninen HI, Lindgren KA, et al. Segmental lumbar spine instability at flexion-extension radiography can be predicted by conventional radiography. *Clin Radiol* 2002; 57(7): 632–639.
5. Dvorák J1, Panjabi MM, Chang DG, et al. Functional radiographic diagnosis of the lumbar spine. Flexion-extension and lateral bending. *Spine (Phila Pa 1976)* 1991; 16(5): 562–571.
6. Fujiwara A, Lim TH, An HS, et al. The relationship between disc degeneration, facet joint osteoarthritis, and stability of the degenerative lumbar spine. *J Spinal Disord* 2000; 13: 444–450.
7. Périé D and Curnier D. Effect of pathology type and severity on the distribution of MRI signal intensities within the degenerated nucleus pulposus: Application to idiopathic scoliosis and spondylolisthesis. *BMC Musculoskelet Disord* 2010; 11: 189.
8. Rajasekaran S, Babu JN, Arun R, et al. A study of diffusion in human lumbar discs: A serial magnetic resonance imaging study documenting the influence of the endplate on diffusion in normal and degenerate discs. *Spine* 2004; 29: 2654–2667.
9. Kent DL, Haynor DR, Larson EB, et al. Diagnosis of lumbar spinal stenosis in adults: A meta-analysis of the accuracy of CT, MR and myelography. *AJR* 1992; 158: 1135–1144.
10. Gallucci M, Limbucci N, Paonessa A, et al. Degenerative disease of the spine. *Neuroimag Clin N Am* 2007; 17: 87–103.
11. Splendiani A, Ferrari F, Barile A, et al. Occult neural foraminal stenosis caused by association between disc degeneration and facet joint osteoarthritis: Demonstration with dedicated upright MRI system. *Radiol Med* 2014; 119: 164–174.
12. Jayakumar P, Nnadi C, Saifuddin A, et al. Dynamic degenerative lumbar spondylolisthesis: Diagnosis with

axial loaded magnetic resonance imaging. *Spine (Phila Pa 1976)* 2006; 31: E298–E301.
13. Jinkins JR, Dworkin JS, Green CA, et al. Upright, weight-bearing, dynamic-kinetic MRI of the spine: pMRI/kMRI. *Riv Neuroradiol* 2001; 14: 135.
14. Karadimas EJ, Siddiqui M, Smith FW, et al. Positional MRI changes in supine versus sitting postures in patients with degenerative lumbar spine. *J Spinal Disord Tech* 2006; 19: 495–500.
15. Modic MT, Steinberg PM, Ross JS, et al. Degenerative disk disease: assessment of changes in vertebral body marrow with MR imaging. *Radiology* 1988; 166: 193–199.
16. Lang P, Chafetz N, Genant HK, et al. Lumbar spinal fusion: Assessment of functional stability with magnetic resonance imaging. *Spine* 1990; 15: 581–588.
17. Bram J, Zanetti M, Min K, et al. MR abnormalities of the intervertebral disks and adjacent bone marrow as predictors of segmental instability of the lumbar spine. *Acta Radiol* 1998; 39: 18–23.
18. Aprill C and Bogduk N. High intensity zone: A diagnostic sign of painful lumbar disc on magnetic resonance imaging. *Br J Radiol* 1992; 65: 361–369.
19. Gallucci M, Puglielli E, Splendiani A, et al. Degenerative disorders of the spine. *Eur Radiol* 2005; 15: 591–598.
20. Splendiani A, Puglielli E, De Amicis R, et al. Spontaneous resolution of lumbar disk herniation: Predictive signs for prognostic evaluation. *Neuroradiology* 2004; 46: 916–922.
21. Ko S, Vaccaro AR, Lee S, et al. The prevalence of lumbar spine facet joint osteoarthritis and its association with low back pain in selected Korean populations. *Clin Orthop Surg* 2014; 6: 385–391.
22. Wiltse LL and Rothman LG. Spondylolisthesis: Classification, diagnosis and natural history. *Semin Spine Surg* 1989; 1: 78–94.
23. Wiltse LL, Newman PH and Macnab I. Classification of spondylolisis and spondylolisthesis. *Clin Orthop Relat Res* 1976; 117: 23–29.
24. Nachemson AL. Instability of the lumbar spine: Pathology, treatment, and clinical evaluation. *Neurosurg Clin N Am* 1991; 2: 785–790.
25. Carragee EJ, Paragoudakis SJ and Khurana S. Lumbar high-intensity zone and discography in subjects without low back problems. *Spine* 2000; 25: 2987–2992.
26. Friederike L, Tamás FF, Dieter G, et al. Lumbar facet joint effusion in MRI: A sign of instability in degenerative spondylolisthesis? *Eur Spine J* 2012; 21: 276–281.
27. Perri M, Grattacaso G, di Tunno V, et al. T2 shine-through phenomena in diffusion weighted MR-imaging of lumbar discs after oxygen-ozone discolysis: A randomized, double-blind trial with steroid and O2-O3 discolysis versus steroid only. *La Radiologia Medica* 2015; 6[Epub ahead of print.
28. Perri M, Grattacaso G, Di Tunno V, et al. MRI DWI/ADC signal predicts shrinkage of lumbar disc herniation after O2-O3 discolysis. *Neuroradiol J* 2015; 28: 198–204.
29. Barile A, Limbucci N, Splendiani A, et al. Spinal injury in sport. *Eur J Radiol* 2007; 62: 68–78.
30. Splendiani A, Perri M, Conchiglia A, et al. MR assessment of lumbar disk herniation treated with oxygen-ozone diskolysis: The role of DWI and related ADC versus intervertebral disk volumetric analysis for detecting treatment response. *Neuroradiol J* 2013; 26: 347–356.
31. Enyo Y, Yamada H, Kim JH, et al. Microendoscopic lateral decompression for lumbar foraminal stenosis: A biomechanical study. *J Spinal Disord Tech* 2014; 27: 257–262.