

Original Article

## Dynamic imaging of the spine with an open upright MRI: present results and future perspectives of fmri

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### Abstract:

This review illustrates the potential of a new upright MRI to reveal “occult” dynamic lesions within the spinal canal and the neural foramina, i.e., pathologic changes that were under-estimated or not seen using recumbent-only imaging.

“fmri” stands for functional MR imaging, mainly of the degenerative and postoperative spine, although it may also detect posttraumatic instabilities and malformations.

**Keywords:** Functional MRI – Spine – Imaging – Upright MRI – MRI - fmri

### Résumé:

Ce travail démontre le potentiel diagnostique d’une nouvelle IRM ouverte en charge dans le diagnostic de lésions dynamiques «occultes» du canal rachidien et des trous de conjugaisons: Des pathologies sous-estimées

ou non visibles lors d’examens effectués uniquement en position couchée.

«fmri» est l’abréviation pour l’IRM fonctionnelle avant tout du rachis dégénératif et postopératoire, tout en soulignant que des lésions traumatiques et malformatives peuvent aussi être mises en évidence.

**Mots clés:** IRM fonctionnelle – Rachis – Imagerie – IRM dynamique – IRM -fmri

### Introduction:

Spinal surgeons have been frustrated for years by the insufficient correlation between diagnostic imaging and clinical syndroms originating from the spine. This has not only been the case during preoperative planning discussions, but also during surgery, where pathologic findings under-reported by the radiologists had to be dealt with.

In a comment for the Journal Spine<sup>(1)</sup>, Gollogly recently pointed at the lack of concordance between the position in which patients

experience pain and the positions that are amendable to plain film, computed tomography, or magnetic resonance imaging. Dynamic changes in all the planes (uncluding sagittal alignment) that occur under loading and during motion are up to now often incompletely understood and must play a significant role in why and when symptoms occur in the degenerative, but also in the posttraumatic spine.

There was a need for future developments in functional clinical imaging that will help all of us to better understand the pathophysiology of the spine by showing pictures correlating to the complaints and the clinical findings, including neurological abnormalities of the patients. This is particularly true for dynamic compressions of neural structures related to a decrease of spinal stability.

Imaging the weight-bearing spine with kinetic maneuvers is now possible with a new Upright MRI unit (Fonar Corporation, Melville, NY). Studies obtained at the fmri center in Zurich <sup>(2-5)</sup> confirm the positive statements made by the pioneers, as published by Jinkins et al <sup>(6-9)</sup>.

Patients with a history of recurrent positional or motion-dependent pain and/or neurological dysfunction of the cervical and lumbar spine were investigated in the upright-seated or standing position, including neutral and flexion-extension imaging.

### **Recent clinical and research developments:**

A position-dependent appearance or increase of posterior disc protrusions, a varying degree of central canal and foraminal stenosis, and of mobile spinal instability (spondylolisthesis) was demonstrated in

cases with preceding less remarkable or even negative recumbent MRI examinations.

Illustrative cases include a L4/5 synovial cyst compressing the thecal sac during retroflexion only, where the ap diameter of the canal additionally decreased. In the flexion study, there were only synovial fluid accumulation visible inside the distended intervertebral joints, and no critical narrowing of the central canal. (Fig 1-2).



Fig. 1: Upright flexion axial view showing bilateral L4/5 joint effusions of the slightly distended intervertebral joints.

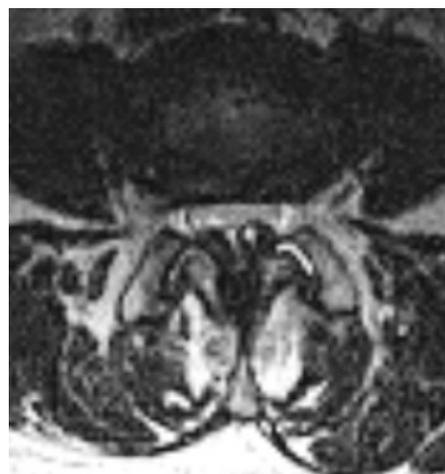


Fig. 2: The upright extension axial view shows a severe dynamic L4/5 central canal stenosis with

additional compression by a left sided synovial cyst not visible during anteflexion.

Unilateral (left) sciatic pain in a football player could be correlated to a load and position-dependent left foraminal stenosis developing in upright position, and increasing even more in extension, while the diameter looked normal in flexion and recumbency. (Fig. 3-5).



Fig.3: The upright-flexion image shows no major abnormality.

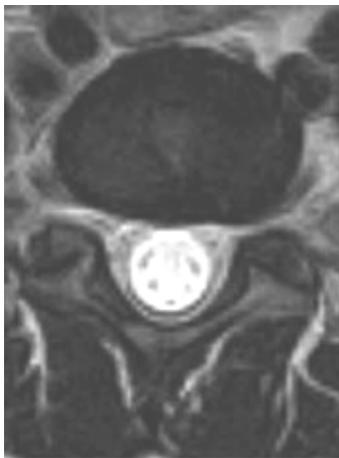


Fig.4: The upright-neutral image shows a left foraminal stenosis.



Fig.5: Upright-extension position: Evident bilateral worsening of the foraminal stenosis, left more than right, as compared to the flexion and neutral position.

A Type I Chiari Malformation, with positional increase of cerebellar tonsils downward herniation and brainstem compression was identified in a patient studied for a C5/6 degenerative disc disease. (Fig. 6-7). At this level an increased disc protrusion and segmental kyphosis was seen during upright imaging<sup>(4)</sup>.



Fig.6: Recumbent cervical MRI showing a bulging disc C5/6 in a patient with neck pain sometimes irradiating to the arms.



Fig.7: Upright MRI from the same patient showing an increasing C5/6 disc protrusion with segmental kyphosis, and in addition a descensus of the cerebellar tonsils behind the lamina of C1 with a medullary compression. This position-related downward herniation (Chiari I malformation) with the compression of the brain stem correlates with the additional complaints of dizziness and occasional drop attacks while bending

forward. This FMRI discloses a double pathology in a patient referred for suspected degenerative disc disease.

(From ref. 4)

Other case examples include cervical and lumbar unilateral and bilateral spinal instability, lateral, rotational instability, dynamic spinal cervical and lumbar stenosis and position-dependent disc herniations.

In patients with prior spinal fusion procedures, motion and axial loading-dependent mobile stenosis/instability at an adjacent segment were detected.

A garage mechanic, who had undergone percutaneous discectomy and interbody grafting at L3/4 in 1990, with revision by PLIF for nonunion in 1991, remained painfree and able to work until early 2006. He developed 15 years later a dynamic L4/5 stenosis with vertical instability and loss of lordosis. A L4/5 decompression with PLIF was now performed with good initial results(Figs 8-9-10-11-12-13).



Fig. 8: Loss of L4/5 disc height and lordosis infrajacent to prior L3/4 interbody fusion performed 15 years ago.



Fig. 9: Dynamic L4/5 stenosis appearing during retroflexion with posterior disc collapse.



Fig. 10: Axial view in flexion showing a moderate L4/5 stenosis.

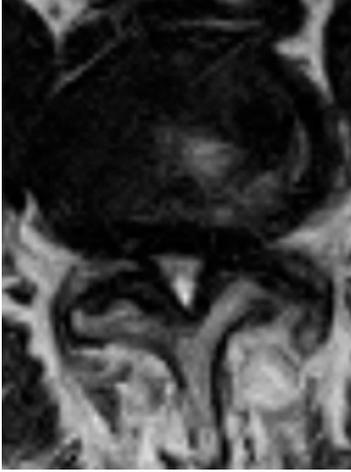


Fig. 11: Axial view in extension showing an evident increase of the L4/5 stenosis.



Fig. 12: Loss of disc height and lordosis at the L4/5 level.

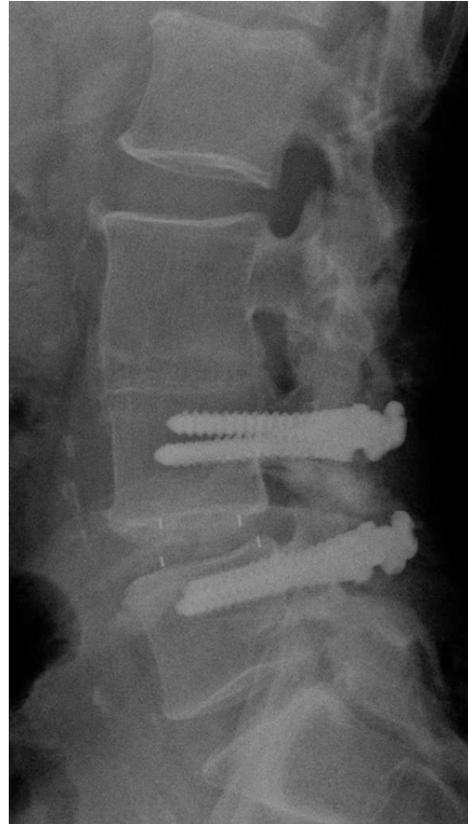


Fig. 13: Correction of L4/5 disc height and lordosis following instrumented PLIF with composite cages and plates.

### **Discussion, future questions and direction:**

Since the pioneering work of Nachemson in 1976<sup>(10)</sup>, we know that intradiscal pressure changes with the position of the individual and increases in standing, sitting and even more in bended forward position. The logical drawback was that changes in a spinal motion segment could be seen more reliably during upright, functional imaging. Some relevant changes have been seen using dynamic myelography, but foraminal pathologies were missed by this invasive technique, and unilateral instabilities remained mostly unrecognized. Cartolari<sup>(11)</sup> promoted the axial-loaded CT and MR technology, where the effect of the body

weight is imitated by pressing with 70% body weight on the patients shoulders, however in the recumbent patient.

Smith et al. <sup>(12)</sup> from the University of Aberdeen, Scotland performed a study of 25 patients with low back pain and sciatica referred for lumbar spine Upright<sup>tm</sup> MRIs following at least one prior “normal” recumbent MRI within 6 months of referral. In 13 patients (52%) fmri demonstrated abnormalities “in one or more of the seated postures that were not evident in the supine (recumbent) examination”. There were 3 cases with lateral disc herniation, 6 cases with hypermobile disc at one or more levels, 2 cases with previously unsuspected Grade I spondylolisthesis and 2 cases with significant spinal canal stenosis. Each of the 13 patients has had an appropriate surgery with successful outcome 6 months post-operatively.

By visualizing position-related alterations in the bony structures and the underlying soft tissues in the upright weight-bearing position, fmri enables the physician to make more accurate decisions regarding treatment options and alternatives, as compared to recumbent MRI. Obviously, undiagnosed dynamic neural compressions cannot be treated efficiently by surgery or other means. As FMRI enables us to plan and perform a more accurate surgical treatment, the rate of the so-called “failed back surgery syndrome” should be diminished. Likewise unnecessary long-term conservative management of now detectable mechanical spinal disorders – which we could call “failed back conservative treatment” – may be avoided.

FMRI has begun to modify the surgical treatment strategies, as it reveals to the surgeons dynamic spinal pathologies that

were frequently underestimated by “conventional” recumbent imaging.

For example, a C3/4 posterior disc protrusion increasing during retroflexion was identified in an ice hockey player who previously experienced an episode of transient traumatic quadriplegia. His spinal canal was rather narrow; there was an associated posterior unilateral instability explaining the secondary cord compression. After anterior C3/4 discectomy and fusion with a composite cage and autologous bone, he was able to return to his training three months after surgery. Other authors have stressed the importance of functional imaging for cervical spine injuries <sup>(13)</sup>. Two patients with head and neck pain were found to suffer from a C1-2 instability following unrecognized odontoid fracture, several years after a car accident. FMRI might help us to better understand possible organic damages following “whiplash injuries”.

Postoperative functional spinal imaging enables the detection of dynamic stenosis/disc protrusion and mobile spondylolisthesis at levels above or below a rigid fusion (provided the patients have no ferromagnetic implants). The so-called „adjacent segment disease“<sup>(14)</sup> is nowadays recognized as late problematic entity in patients with instrumented spinal segments. It may be promoted by insufficient correction of disc height and spinal balance (restoration of physiological lordosis, sagittal alignment) during surgery, but is often the manifestation of an ongoing multilevel degenerative disc disease.

The proper function <sup>(15)</sup> or dysfunction of dynamic stabilizing implants, some of which are popular for their minimal invasiveness, can also be studied by fmri.

## **Conclusion**

This upright MRI is free from the negative effects of radiation and in practice is popular among claustrophobic patients. In present usage, fmri enables better correlation between patient complaints and imaging findings. In the near future it could become the imaging modality required before performing surgical spinal decompression, reconstruction and stabilization procedures. It is only in this manner that the physician can hope to determine critically the anatomic explanation for the patient's clinical syndrome, if the patients experiences pain and disability in any other position than in recumbency. The need for dynamic myelograms will decrease, this invasive technique being useful for patients with ferromagnetic hardware, but not adequate to demonstrate intra- to extraforaminal pathology.

Apart from degenerative disc disease and spondylolisthesis, juvenile scoliosis could potentially be followed benignly by serial fmri. As an added practical point, children can also sit in the MRI scanner while in their mothers lap, and undergo basic cranial or spinal imaging mostly without sedation. FMRI can also be used as an investigational tool, e.g. for whiplash injuries, but also to assess the pathophysiology of functional joint disease. There is a presently not untapped fmri-research potential in sports medicine.

## **References:**

1. Gollogly S (2005) Spine 30(13) 1559
2. Elsig JP, Kaech DL (2005) FMRI for evaluation of the degenerated spine:

- preliminary results. Le Rachis vol.1(4),3
3. Jinkins JR, Elsig JP, Kaech DL (2005) Functional upright-kinetic MRI: Mobile stenosis of the spinal neural foramina, alteration in size of disc herniation and disc herniation missed on recumbent imaging. Interventional Neuroradiology 11 (Suppl 2): 260-270
4. Kaech DL, Elsig JP (2006) Functional imaging of the degenerative spine with an open, upright, weight-bearing, kinetic MRI. ARGOS Spine News 13:11-12
5. Kaech DL (2006) Funktionelle Bildgebung der Wirbelsäule im offenen MRI. Schweiz Med Forum 6:586-589
6. Jinkins JR et al (2002) Upright, weight bearing, dynamic-kinetic MRI of the spine: pMRI/kMRI. Riv di Neuroradiol 15:333-357
7. Jinkins JR, Dworkin JS (2002) Upright, weight bearing, dynamic-kinetic MRI of the spine: p/k MRI. In: Kaech DL, Jinkins JR (eds): Spinal Restabilization Procedures, Elsevier, Amsterdam, pp 73-82
8. Jinkins JR(2003) Positional-kinetic MRI of the spine: p/k MRI. The evolving future responsibility of the medical imaging specialist in diagnostic imaging of the pre- and postoperative spine. Rachis 15:242-243
9. Jinkins JR, Dworkin JS, Damadian RV (2005) Upright, weight-bearing, dynamic-kinetic MRI of the spine: initial results. Eur Radiol 15:1815-1825
10. Nachemson AL (1976) The lumbar spine, an orthopedic challenge. Spine 1:59
11. Cartolari R (2002) Axial loaded computer tomography of the lumbar spine. In: Kaech DL, Jinkins JR (eds) Spinal Restabilization Procedures, Elsevier , Amsterdam, pp 59-65

12. Smith FW et al (2005) Positional Upright Imaging of the Lumbar Spine Modifies the Management of Low Back Pain and Sciatica, European Society of Skeletal Radiology, Oxford, England
13. Fuentes S, Métellus P, Adetchessi I, Dufour H, Grisoli F (2005) Intérêt de l'IRM cervicale dynamique dans la prise en charge de certains patients victimes de traumatismes vertébraux médullaires. RACHIS 51:525-526
14. Kaech DL (2006) Practical dilemmas in the surgical treatment of spinal "adjacent segment disease". In Rudinsky B (ed) Spinalna Chirurgia - Spinal Surgery, Slovak Academic Press, Bratislava, pp 191-199
15. Siddiqui M, Nicol M, Karadimas E, Smith F, Wardlaw (2005) The positional magnetic resonance imaging changes in lumbar spine following insertion of a novel interspinous the distraction device. Spine 30:2677-2682