

Practical Considerations for the Evaluation of the Neuroforamina in Routine Spine Imaging at 3T. A Case Series

Thuy D. Do; Marc-André Weber

Clinic of Diagnostic and Interventional Radiology, University Hospital Heidelberg, Germany

Introduction

Pathologies of the neuroforamina are one of the most frequent indications for spine surgery. When imaging the neuroforamina usually sagittal and axial planes are acquired to delineate these pathologies. However, in a relatively small, but clinically not negligible, 29% of cases where root impingement was surgically confirmed, lateral root compression was underestimated in standard MRI with standard MR planes (axial/sagittal). Moreover, Bartynski et al. estimated the rate of successful prediction of a root impingement with such a standard MRI at only 72% [1]. Consequently there is a need to optimize the procedure for spine MRI to reliably evaluate nerve root impingement in a potential pre-operative setting. By obtaining parasagittal sequences and by performing oblique image reconstructions, one can generate images that are strictly axial cuts through the neuroforamina. This allows for a better evaluation of the nerve enlargement, the disappearance of the nerve surrounding fat, and the provision of T2-neuropathy signals. The application of multiplanar reconstructions, e.g. for sacral nerves, has already been postulated and practiced on CT scans in clinical routine [2]. However, in clinical reality, MRI protocols often still use strictly axial and sagittal 2D planes, resulting in the above-mentioned challenges. In the following cases we present some practical aspects on the imaging protocols used to improve visualization of neuroforaminal pathologies.

Imaging of neuroforaminal pathologies at 3T

At our institute we mainly apply 3T MRI for evaluation of neuroforaminal pathologies. The main advantage of imaging at 3T is the proportional increase of signal-to-noise ratio (SNR), enabling a clear reduction in slice thickness. Even in clinical realistic routine exams, the slice thickness can be reduced to even less than 3 mm for 2D T2-weighted MRI sequences. High SNR also provides better in-plane resolution as well as spatial resolution of the anatomical structures to be evaluated [5]. Although the disadvantages of MR imaging at 3T, such as dielectric shading effects, have to be taken into consideration, many of these limitations have been overcome, or are at least less pronounced, compared to the first clinical generation of 3T MR systems. Nevertheless, it should be emphasized that these dielectric shading effects do play a role in the application of 3T for spine imaging and must be addressed alongside other issues such as increased specific absorption rates. Most of the practical considerations in this case series, however, also apply for spine imaging at 1.5T.

All examinations presented in this article were performed on a 3T MRI scanner (MAGNETOM Verio, Siemens Healthcare, Erlangen, Germany) using the integrated multi-channel spine coil and – for imaging of the cervical spine – the head/neck coil.

Conclusion

Questions concerning pathologies of the neuroforamina, multiplanar reconstructions and/or additional angulated imaging sequences (at a 45° oblique view towards the standard sagittal plane) of the spine should particularly be included in routine examinations for improved delineation and depiction of neuroforaminal pathologies, especially if there is a need to evaluate surgical therapy. Whenever possible, a 3D sequence is preferred and thus post-imaging reconstructions can be compiled that not merely reduce examination time but also offers advantages for multiple planar reconstructions as well as simplifying the MR exam. In other cases, e.g. when dealing with metal instrumentation or motion artifacts due to pain, faster additional T2w sequences can be applied. Kinematic MRI might be beneficial for revealing disc bulges, which are not shown by traditional neutral views and should be considered also in a routine clinical setting for evaluation of the cervical spine.

Acknowledgment

The excellent technical assistance from Mrs. Sandra Kauczor and Joanna Weihrauch-Mohr is gratefully acknowledged.

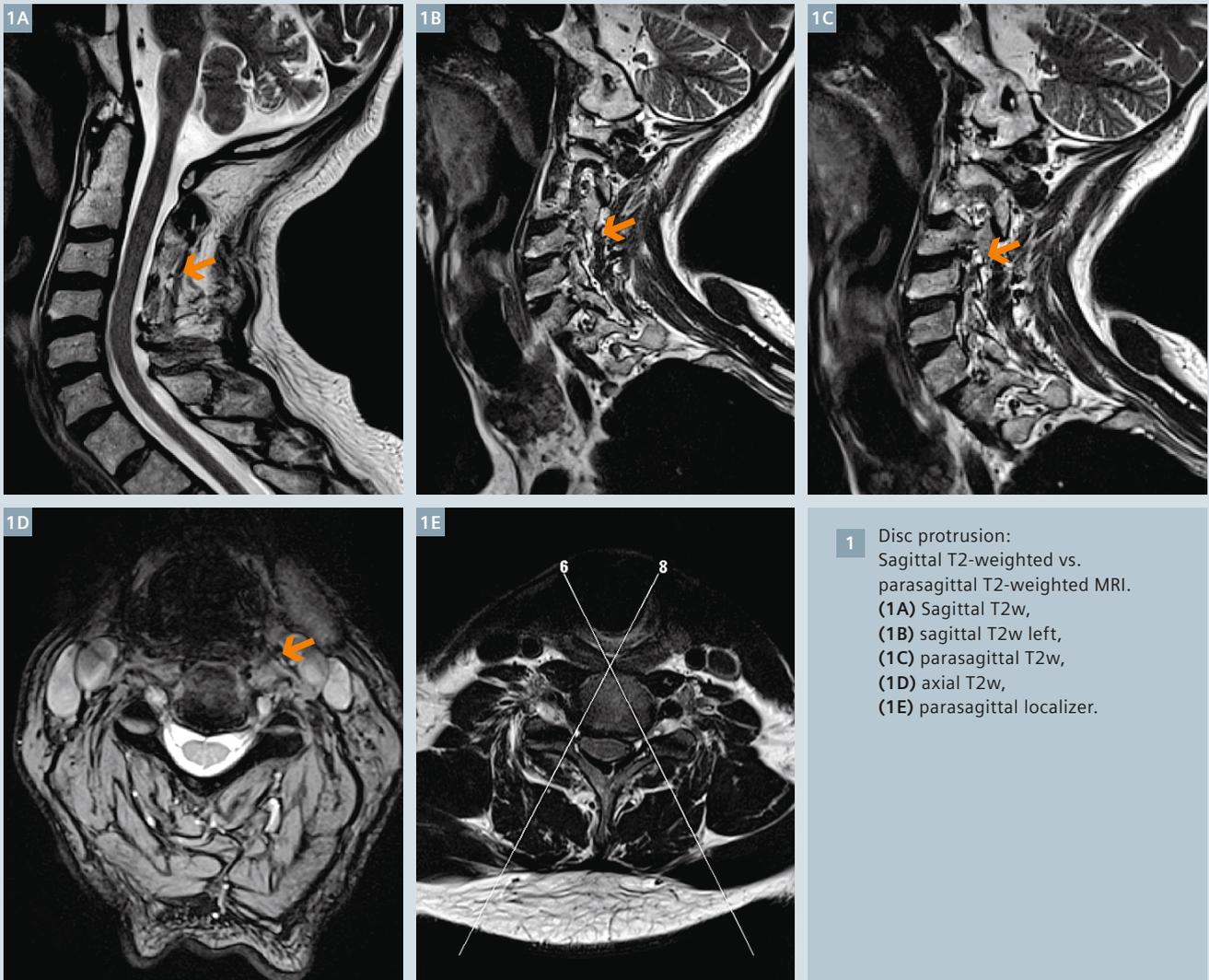
Case 1: Parasagittal oriented T2-weighted sequences

An MRI exam of a 51-year-old male patient suffering pain within the cervical spine predominantly on the left side for the last four years. No focal neurologic symptoms were present. This case shows the value of parasagittal-oriented 2D MR sequences for improved confidence in diagnoses. In the parasagittal sequences, a focal mediolateral protrusion of the disc C3/C4-vertebra with compression of

the left C3 spinal nerve can be easily delineated.

The disc herniation is less obvious due to partial volume effects and could have been missed on the standard sagittal planes, whereas the oblique parasagittal sequence nicely depicts the left sided protrusion (arrows). The parasagittal planes were planned as a 45° oblique angulated plane to the median and perpendicular to the neuroforamina. This case illustrates that by relying

only on standard sagittal and axial 2D MRI for depicting the cervical spine and relatively thick slices (>3 mm), the diagnostic information may be limited for a proper evaluation of the nerve roots. In addition to the said protrusion, an old fracture of the spinous process C7 and Th1 was diagnosed.



1 Disc protrusion: Sagittal T2-weighted vs. parasagittal T2-weighted MRI. (1A) Sagittal T2w, (1B) sagittal T2w left, (1C) parasagittal T2w, (1D) axial T2w, (1E) parasagittal localizer.

		TA [min]	Matrix	FOV [mm]	Slices	ST	TR [ms]	TE [ms]
Cervical spine	Parasagittal T2w TSE	2:13	384	260	11	2	2690	110

Table 1: Parasagittal T2-weighted TSE sequence used in this case for improved visualization of the neuroforamina.

Case 2: 3D T2-weighted sequences and parasagittal image plane reconstructions

In contrast to oblique-oriented 2D MR sequences, 3D MR sequences allow in retrospect any necessary reformation and are less dependent on accurate planning of the exam. Furthermore, there are obvious time benefits where multiple planes are needed. However, the differences in contrast and image impression (high resolution in-plane versus isotropic voxels resulting in thin slices with reduced in-plane resolution) compared with conventional 2D MRI sequences should be mentioned, even though they are not covered in this article.

In this case, MR images were made of a 52-year-old male who presented with pain in the lower back, radiating in the legs. Standard 2D MRI based on axial and (para-) sagittal planes showed disc protrusion of the L4-S1 vertebra with the maximum of the herniation at the L4/L5 segment.

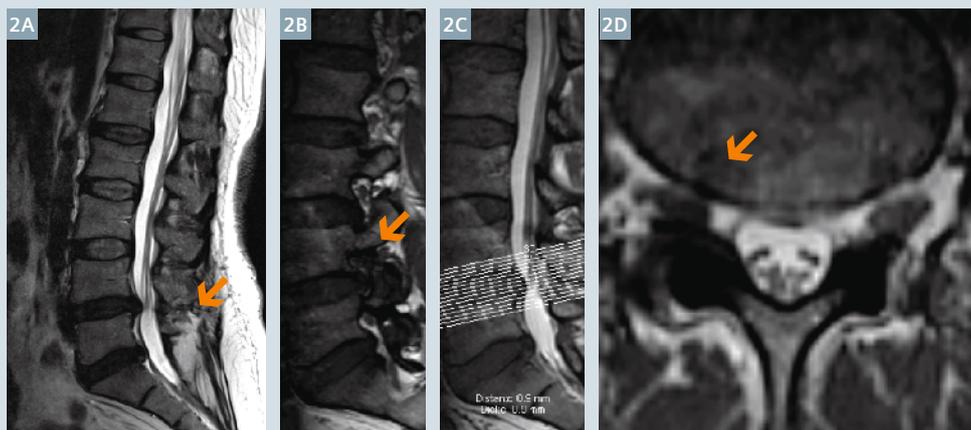
There was a narrowing more of the right neuroforamen than of the left neuroforamen at the L4/L5 segment due to the disc protrusion as well as spondylarthrosis.

In addition to the standard MRI protocol, we used a balanced steady-state free precession sequence (TrueFISP), which provides a high signal intensity of the cerebrospinal fluid. As shown in figure 2B, the oblique reconstruction improves the confidence of the finding. With its short acquisition time, this TrueFISP sequence is also less sensitive to motion artifacts. To achieve a similar contrast of the cerebrospinal fluid other sequences can also be used, e.g. 3D CISS sequences. However, it should be pointed out that at 3T we must also keep the flip angles under observation because of their effect on the specific absorption rate (SAR) [3].

One drawback of the TrueFISP sequence is the so-called dark band-

ing artifact which can be met by acquiring images at different phase offset angles. Another alternative would be the application of the SPACE sequence for T2w 3D imaging at 3T.

By allowing multiplanar oblique reconstructions, the additional 3D sequence reduces the risk of missing neuroforamen encroachment, without the need for further sequences and without increasing the complexity of the procedure for the MR scan. Although the lumbar neuroforamina have a nearly sagittal orientation to the lumbar spine and are in most cases well depicted with traditional location of planes, these additional images provided by the TrueFISP that depict the neuroforamina en face facilitate the detection of even minor encroachments. In addition, the higher spatial resolution can improve the diagnostic confidence for the conventional planes e.g. as shown in this case, for a strictly axial orientation (Fig. 2C).



2 Disc protrusion: Sagittal T2-weighted sequence vs. parasagittal TrueFISP reconstructions and strictly axial reconstructions along the disc. (2A) Sagittal T2w, (2B) parasagittal reconstruction, (2C) localizer, (2D) axial reconstruction.

		TA [min]	Matrix	FOV [mm]	Slices	ST	TR [ms]	TE [ms]
Sequence	Cor TrueFISP 3D	4:26	256	220	80	0.9	4.86	2.43
Lumbar spine reconstructions	Axial		256		Variable	1	4.86	2.43
	Parasagittal reconstruction angulated towards the neuroforamina		256		Variable 30	1	4.86	2.43

Table 2: TrueFISP sequence and parasagittal reconstructions.

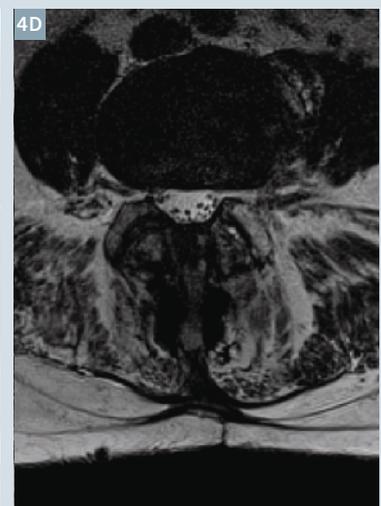
Case 3: Parasagittal and oblique oriented MR sequences in case of indwelling metal

In this case MRI images were made of a 76-year-old female who presented with a one-year history of back pain spreading more in her right than her left leg. Two years ago a spacer between the spinous processes L4/L5 had been implanted at another hospital.

In this case, a conventional parasagittal plane represents a good option for postoperative imaging, since metal susceptibility artifacts are avoided. But depending on the implant used and its configuration, the usage of double oblique planes offers the opportunity that the artifact generated by the osteosynthesis instrumentation moves out of the field-of-view. We prefer conventional T2-weighted TSE sequences in patients with surgical hardware and in combination with different angulations: Often good, robust imaging is feasible even with the pronounced sensitivity of 3T towards artifacts introduced by these implants. Since 3D gradient echo sequences, like the MEDIC, are more prone to susceptibility artifacts, they do not represent the backbone of our protocol. However, for instance 3D SPACE sequences have the advantage of post-imaging reconstructions which may be required especially in very complex cases and instrumentation e.g. severe scoliosis and rotation of the spine. As demonstrated in figure 4, the instrumentation does not affect the diagnostic quality of the MR scan and the neuroforamina can be assessed adequately.



3 X-rays of lumbar spine with osteosynthesis material between the spinous process L4/L5.



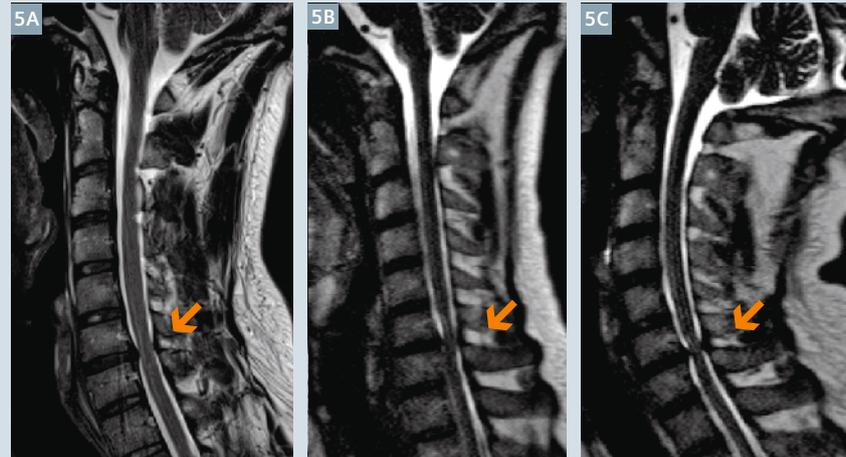
4 Sagittal vs. parasagittal oriented T2-weighted TSE sequences. (4A) Sagittal T2w, (4B) parasagittal T2w left, (4C) parasagittal T2w right, (4D) axial T2w.

Case 4: Additional value of dynamic MRI sequences

For the evaluation of pathologies of the cervical spine in particular, dynamic MRI sequences can add important clinical information, obtained within a routine clinical setting. In this case, a 42-year-old man with persisting pain in the cervical spine presented for MR reevaluation after a car accident two years ago. He has no focal paresis, only paresthesia in his left thumb. The kinematic MRI comprised of ultrafast sequences (e.g. T2-weighted HASTE) at 30° inclination and reclination. At the neutral position a disc bulge and myelopathy signal are denoted at the C6/C7 level indicating the cause of the symptoms. The disc bulge was significantly increased in extension (reclination) position (Fig. 5C). This case illustrates well the valuable information obtained by adding a 30-second sequence to the standard MRI protocol. Sometimes abnormalities can only be depicted – or are better depicted – by flexion or extension

of the spine so that the symptoms are at their maximum. This method may be restricted, apart from contraindications, if there is severe pain that renders the patient unable to bear this position. Nevertheless, the application of a HASTE sequence represents a good approach that allows in most cases such a dynamic

scan. Other sequences, like conventional 2D TSE, or even 3D sequences like SPACE or TrueFISP do, of course, offer all the advantages discussed above, but they are coupled with longer examination times and sequence-dependant challenges such as sensitivity to metal artifacts [4].



5 Conventional sagittal T2w vs. dynamic T2w MRI. (5A) Sagittal T2w, (5B) T2w HASTE inclination, (5C) T2w HASTE reclination.

		TA [min]	Matrix	FOV [mm]	Slices	ST	TR [ms]	TE [ms]
Cervical spine inclination	T2w HASTE sag	0:30	320	250	15	3	1000	249
reclination	T2w HASTE sag	0:30	320	250	15	3	1000	249

Table 3: Dynamic sequences.

References

- 1 Bartynski, W.S. and L. Lin, Lumbar root compression in the lateral recess: MR imaging, conventional myelography, and CT myelography comparison with surgical confirmation. *AJNR Am J Neuro-radiol*, 2003. 24(3): p. 348-60.
- 2 Yang, J., et al., Application of MPR in sacral nerve injury during sacral fracture. *J Trauma*, 2011. 70(6): p. 1489-94.
- 3 Baskaran, V., et al., Myelographic MR imaging of the cervical spine with a 3D true fast imaging with steady-state precession technique: initial experience. *Radiology*, 2003. 227(2): p. 585-92.
- 4 Gerigk, L., et al., Dynamic magnetic resonance imaging of the cervical spine with high-resolution 3-dimensional T2-imaging. *Clin Neuroradiol*, 2012. 22(1): p. 93-9.
- 5 Shapiro, M., Imaging of the spine at 3 tesla. *Neuroimaging Clin N Am*, 2012. 22(2): p. 315-41, xi-xii.



Thuy D. Do

Marc-André Weber

Contact

Marc-André Weber, M.D., M.Sc.
 Professor of Radiology
 Heidelberg University Hospital
 Diagnostic and Interventional Radiology
 Im Neuenheimer Feld 110
 69120 Heidelberg, Germany
 MarcAndre.Weber@med.uni-heidelberg.de

Save the Date

Heidelberg Summer School

Musculoskeletal Cross Sectional Imaging 2015

July 24th / 25th 2015
Heidelberg, Germany

The Heidelberg Summer School offers advanced learning opportunities and promotes the academic exchange of knowledge, ideas, and experiences by bringing together physicians and professional staff from all over the world. Excellent speakers will cover a wide range of medical, physical, and technical topics in musculoskeletal imaging. All lectures are in English.

Course director

Marc-André Weber, M.D., M.Sc.

Professor of Radiology, Section Head Musculoskeletal Radiology at the University Hospital Heidelberg

CME Accreditation

The symposium will be accredited by the 'Landesärztekammer Baden-Württemberg' with CME credits (category A).

Also, the symposium is accredited for 1 category 3 credit point for the ESSR diploma by the European Society of Musculoskeletal Radiology.

Registration

Mrs. Marianne Krebs, Secretary of the Section Musculoskeletal Radiology

Marianne.Krebs@med.uni-heidelberg.de

For further information please visit:

www.heidelbergsummerschool.de

