Advantages of MSK Imaging at 3 Tesla with special focus on Spine and Tumor Imaging

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Background

In 2009, our institution, the Department of Diagnostic and Interventional Radiology, had to decide for a replacement of an existing 1.0 Tesla MR system with conventional coil technology and a bore-size of 60 cm at the Department of Orthopedics with the main departments Orthopedics and Traumatology as well as Paraplegiology and Rehabilitation Medicine. While the clinicians were satisfied with the robustness of imaging in case of metal implants with the old scanner, compromises in image resolution and relatively long examination times as well as the missing capabilities of the old system for scanning multiple regions of interest within one examination without the need for patient repositioning did limit the usage of MRI. In addition, due to the limited signal-to-noise ratio (SNR) as a result of the low field strength and old coil technology implemented in this system, the increasing clinical demand for widening the application of MRI to include, for example, molecular assessment of cartilage repair or multi-region tumor staging in children and adults could not be fulfilled sufficiently in a clinical environment. The advantages of 3 Tesla especially for orthopedic imaging are well known: increase in SNR (proportional increase of the SNR with the increase of the field strength) and less prominent effect of B1 inhomogeneity on image quality for most areas of interest in musculoskeletal (MSK) imaging (knee, shoulder, ankle, wrist etc.) results in clearly improved image quality (resolution wise) and/or faster scan times. However, for advanced spine imaging as well as tumor staging, the "dielectric shading" effects would again have limited the usability of the MRI scanner. But with the development of anatomy optimized amplitude and phase transmission settings for homogenous B1 radio-frequency (RF) transmission and in combination with further optimizations of the magnet and gradient design (TrueForm technology), local signal drop out at 3T can be reduced significantly if not even eliminated practically.

Another limitation of higher field strength is the higher energy deposit within tissue, resulting in higher specific absorption rate (SAR). And finally, metallic implants will result in increased signal drop due to pronounced susceptibility artifacts [Fries 2008, Baudendistel 2004]. But these effects with negative impact on the image quality and examination time can again significantly be reduced if not compensated by new MR technology (e.g. adopting sequence techniques and application of parallel imaging techniques). Finally, we were convinced that the advantages of the 3T technology available with the new scanner generation do outweigh the disadvantages significantly. In spring 2009 we therefore decided for replacement of our old 1T scanner by a 3T MAGNETOM Verio. We would like to present below some interesting cases out of our daily clinical routine which demonstrate the advantages of MSK imaging at 3T with special focus on spine and tumor imaging.

Case 1

As a center dealing with a high number of patients with hemi- or paraplegia, cerebral palsy as well as scoliosis, the 70 cm open-bore system has the advantage of a very flexible patient positioning. As demonstrated in figure 1B, especially severe contractions of the extremities often seen in these patients do require sufficient space in the anterior-posterior direction. In figure 1A our MR-compatible wheelchair is shown, which enables an easy and relative fast patient transport into the scanner.
Case 2
This case demonstrates our standard imaging strategy in case of lower back pain. We apply mainly turbo spin-echo (TSE) sequences for this purpose. Sequence parameters for the shown images are:

**T1w TSE sagittal:** resolution (0.7 x 0.7 x 3.0) mm³, TR 684 ms, TE 12 ms, TA 2:48 min (fig. 2A).

**T2w TSE sagittal:** resolution (0.7 x 0.7 x 3.0) mm³, TR 3650 ms, TE 113 ms, TA 3:00 min (fig. 2B).

**T1w TSE axial (oblique):** resolution (0.7 x 0.7 x 3.0) mm³, TR 969 ms, TE 12 ms, TA 3:09 min (fig. 2C).

**T2w TSE axial (oblique):** resolution (0.7 x 0.7 x 4.0) mm³, TR 5060, TE 115 ms, TA 2:59 min (fig. 2D).

With a total scan time of less than 15 minutes, this protocol focuses on a fast assessment of the lumbar spine. However, because of the higher signal-to-noise contribution of the 3 Tesla system in combination with the integrated multi-channel spine coil, also a relatively high sub-millimeter in-plane resolution at slice thicknesses of 3 mm for sagittal and transversal planes is achieved.

In this particular case, a medio-lateral large hernia of the intervertebral disc of L5/S1 with compression of the left nerve root is seen (arrows).

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**Case 3**
In case of malignancies or inflammation, however, we have to expand our clinical routine protocol. This case shows selected images of a 63-year-old male patient with known spinal astrocytoma WHO grade III. This patient underwent chemo- and radiotherapy and presented at our institution with clinically stable paraplegia at the level of Th5. A swollen myelon can be seen in this follow-up exam at the height of the irradiated tumor at the height of thoracic vertebra 6–8. On post-contrast T1w MRI, an inhomogeneous medullar enhancement can be seen (arrow). Note that the patient also underwent laminectomy and that a residual seroma can be detected. Enhancement within the vertebra was stable over a long period of time and based also on CT imaging, this finding has to be classified as a hemangioma of the 9th thoracic vertebra.
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Case 6

Complex congenital malformation of the central nervous system, as well as the spine, requires also evaluation of the whole systemic aspect of disease. In this case, we show images from a 15-year-old boy with Arnold Chiari II malformation and lumbal meningocelele (closed by surgery after birth). Because of severe and progedient complex scoliosis, this patient also underwent a dorsal spine fusion of Th9 downwards to the pelvis with VEPR instruments and underwent multiple extensions (conventional x-ray Fig. 6A).

Figures 6B and C do show the image quality difference between 1 and 3T exam (both 3 mm slice thickness). Again, the superior SNR and in-plane resolution allows for a more detailed assessment of the meningocelele (arrows). Especially T2w 3D imaging allows for a detailed assessment of all aspects of the impairment of the central nervous system including the myelon and nerve roots. Figure 6D shows the results of a syngo SPACE exam of the whole spine. The meningocelele is resolved in detail (arrow) as well as the displacement of the cerebellum as part of the Arnold Chiari malformation. Also tethering of the myelon, which is important for the orthopaedic surgeons to know about because it must be resolved before any operation to the spine, is well depicted. Note also the displacement of inner organs in this case (asterisk marks one of the kidneys).

Case 7

Exam of a 59-year-old male patient with complete tetraplegia at the level of C5 and secondary syringobulbia starting at the vermis down to the 6th thoracic vertebra as a consequence of a bathing accident in 1968. The patient received arachnolysis and dural plastic as specific therapy, as well as a wound examination because of a liquor pad. The syngo SPACE exam (Fig. 7A) shows multiple horizontal septae, which divide the syrinx and might hinder CSF exchange and thus might cause extension of the syrinx. The 3 Tesla T2-weighted image (Fig. 7A) better delineates the septae than the 1 Tesla T2-weighted image (Fig. 7C). In this case, a complete suppression of the liquor was seen on FLAIR images (not shown), suggesting communication of the multiple cystic lesions and the subarachnoid space.
Orthopedic Imaging

**Case 8**
Intramedullar formation of cavities can often be found as a consequence of widening of the central canal (hydromyelia) or outside the central canal (syringomyelia) as result of traumatic events or space occupying lesions/tumors or as a malformation. T2w images of a 7-year-old boy are shown, showing a syringomyelia affecting the whole myelon (holocord syrinx).

**Case 9**
10-year-old girl with meningomyelocele, paraparesis, spina bifida and rotation scoliosis is present as well as dysplasia of the 12th thoracic vertebra. Imaging was conducted for planning of specific therapy including instrumented dorsal spine fusion and decompression of the spinal canal. For optimal outcome and for best risk stratification of such a therapy, detailed information not only about the complexity of the disorders of the spine but also of the myelon and nerve roots is essential. CT (volume rendering shown in Fig. 9A) as well as 3T MRI demonstrated in detail the known left convex rotation scoliosis of the thoraco-lumbar spine. Syrinx from level Th3 down to the conus is visualized by MRI (arrows in Figs. 9B–D). In addition, starting at the height of Th6, a T2w hypointense, T1w isointense to the myelon, linear and parallel to the myelon running structure can be delineated that might resemble a scarred cord. Most probably this structure represents split cord malformation e.g. diastematomyelia.
Case 10

Results of an MRI scan of an 87-year-old female patient with dementia and severe back pain are shown. Severe motion artifacts were present (Fig. 10A) but could be compensated by applying motion-insensitive (syngo BLADE; Fig. 10B) MR sequences and fast sequences with parallel imaging (post-contrast T1w image; Fig. 10C). Spondylodiscitis and complete destruction of the intervertebral space of L5/S4 is seen. In addition, multiple epidural abscesses can be seen. The patient underwent surgery with dorsal and ventral spine fusion, open discectomy and laminectomy as well as drainage.

Conclusion

Although the adoption to the higher field strength of 3T, new coil technology and multi-region exams were challenges to radiologists, technologist and referring clinicians and do require a (short) transition phase, the clinical advantages are significant, as shown with this case series. After approximately one year of operation, the installation of the 3T open bore system with TrueForm technology has clearly improved our diagnostic potential as well as widened the indications for MRI and has lead to improved patient care. The system is therefore well received among our clinical colleagues, resulting also in a significant increase of referrals during the last year. In addition, the patient comfort of the open bore system has resulted in a higher acceptance of MRI by patients.

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Musculoskeletal Advisory Board Provides Protocols for 1.5 and 3T MAGNETOM systems

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