Univ. Prof. Dr. Siegfried Trattnig graduated from the University of Vienna Medical School in 1985. He trained in Radiology and subsequently served as Assistant Medical Director and Acting Medical Director for the Section of Neuroradiology in the Department of Radiology, Medical University of Vienna. He was appointed as an Associate Professor in Radiology 1993 becoming the Acting Medical Director at the Clinical Magnetic Resonance Institute at the University of Vienna. Since 2003 Prof. Trattnig has the position of the Medical Director of the Centre of Excellence in High-Field MR at the Medical University of Vienna. In 2010 he was appointed as a full Professor for Radiology with special focus on High field MR. Prof. Trattnig has pioneered the field of multi parametric or biochemical MR imaging of cartilage. He is currently the lead researcher on the clinical 7T & 3T projects at the Medical University in Vienna. Based on the results of clinical comparison studies between 3 and 7T his Center of Excellence for High Field MR was appointed as the international Reference Center for 7 Tesla by Siemens Healthcare, the leading vendor in the ultra-high-field MR. He is editorial board member of 8 scientific journals, is or was member of 35 committees and working groups within the ISMRM, ESR, ESMRMB and the ICRS among them he has been Executive Board member of the ESMRMB, member of the ESR Research Committee Board and Chairperson of the ESR European Imaging Biomarker Alliance (EIBALL) and Director of the School of MRI of the ESMRMB. He is an author of 532 articles in peer reviewed scientific journals and contributed to 25 scientific books. Additionally he has held 26 peer reviewed scientific grants with a total of funding money of 13.5 Mio €, received 12 scientific awards and is a reviewer for 35 scientific journals.

Exploring New Frontiers in MRI 7-Tesla MRI Goes Clinical – a Personal View

Dear readers and colleagues,

I have been asked to introduce this ISMRM edition of MAGNETOM Flash by taking a look to the future of MRI. The articles cover a range of aspects that reflect the latest developments. They also look at AI and the wide field of digitalization in healthcare – developments that no longer lie ahead, but are already happening. Winkel and colleagues, for instance, describe Prostate AI[1]. This end-to-end concept enables a standardized workflow with reproducible and fast data acquisition, optimized imaging sequences, and AI-powered data analysis. It includes automated detection, classification, and reporting of suspicious lesions in biparametric prostate MRI examinations. Elizabeth Morris's assessment of breast cancer phenotypes using MRI biomarkers in clinical practice shows how machine learning and radiomics are already influencing professionals and the patient experience. Other articles reflect how quantification has reached clinical routine: Frittoli and colleagues describe quantifying liver fat and iron using LiverLab, while Gregor Körzdörfer shares new developments in the success story of MR Fingerprinting[2]. With a focus on reaching underserved populations and using MRI in settings such as the emergency room, field strength might also be under discussion going forward. Salameh and Sarracanie address this topic in their article on re-envisioning low-field MRI. At the other end of the spectrum, ultra-high-field MRI is attracting increasing interest because of the improved clinical results it can deliver thanks to its morphological, functional, and metabolic capabilities.

Our High Field MR Centre (HFMRC) in Vienna is an interdisciplinary platform for methodological development and basic science research in the field of whole-body high-field MR (3 tesla and 7 tesla) with a clinically oriented approach. The flagship resource of the HFMRC is a 7T research system (Siemens Healthcare, Erlangen, Germany) with multinuclear capability and 8-channel parallel transmit. In addition, the centre houses two state-of-the-art 3T MRI scanners which are used for research.

Compared to other ultra-high-field installations, the HFMRC has the advantage of being located close to Vienna General Hospital, one of the largest university hospitals in Europe. This proximity makes it possible to combine method development with translational and clinically applied research.

[1]Work in progress: the application is currently under development and is not for sale in the U.S. and in other countries. Its future availability cannot be ensured.
[2]MR Fingerprinting is not commercially available in some countries. Due to regulatory reasons its future availability cannot be guaranteed. Please contact your local Siemens organization for further details.

In this particular field, not only may basic research be of interest, but also clinically oriented patient trials that demonstrate the clinical feasibility of nuclei other than protons and their clinical benefit as unique features of 7T.

When we started operating our 7T research system more than ten years ago, my group and I realized that, in contrast to many other 7T sites which were focused on hardware development, our strength at the Vienna site was clinically oriented research at 7T with large departments at Vienna General Hospital and many clinical experts in different fields.

Collaboration is key

Since I personally experienced the fast development of 3T from pure research scanners to commercially available routine scanners – the shift from 1.5T to 3T took only a few years – my vision as a radiologist for 7T was to see a similar transition from 3T to 7T. To make this crucial step, several elements were necessary. First, we needed excellent collaboration with the MR scanner vendor, Siemens Healthineers. This would enable us to develop and optimize routine clinical MR protocols for 7T which could use the additional signal-to-noise ratio for higher resolution protocols at 7T in the same scan time as 3T, with a consecutive benefit in morphological imaging. In a series of sequences, patient comparison studies in neuro and MSK routine imaging at both field strengths had to be performed to evaluate the diagnostic confidence at 3T and at 7T. In addition, and in parallel to these basic studies, unique features of 7T had to be demonstrated in clinical trials. Beyond morphological imaging, another strength of 7T is the X-nuclei option, i.e., the application of other nuclei such as sodium imaging, phosphorus spectroscopy, and carbon spectroscopy at 7T. In this particular field, not only may basic research be of interest, but also clinically oriented patient trials that demonstrate the clinical feasibility of nuclei other than protons and their clinical benefit as unique features of 7T.

My vision became reality when Siemens Healthineers made the strategically important decision to develop an ultra-high-field clinical MR scanner: the MAGNETOM Terra system. Our abovementioned comparison studies examined 40 patients with neurological disorders and 40 patients with knee pain using 11 sequences at 3T and at 7T. They clearly showed higher diagnostic confidence at 7T than 3T, and were very helpful in acquiring FDA approval and CE certification for the MAGNETOM Terra system in 2017 [1, 2].

Advanced therapy results

Our ultra-high-field clinical research has contributed to a variety of fields.

As the signal-to-noise ratio scales supralinearly with the field strength (B_0) of the scanner, the most obvious application at 7T is for obtaining higher spatial resolution in the brain, musculoskeletal system, and breast. When imaging the hippocampus, we could demonstrate that even subfields of the internal hippocampal anatomy and pathology can be visualized with excellent resolution, which provides a predictive marker for surgical outcome in patients with intractable temporal lobe epilepsy [3]. The dynamic and static blood oxygenation level-dependent contrast increases supralinearly with the field strength. This significantly improves the presurgical evaluation of eloquent areas before tumor removal, especially in critical cases where the tumor is very close to vital regions of the brain and high fMRI accuracy and spatial resolution are required [4]. Using susceptibility-weighted imaging, the plaque-vessel relationship and iron accumulation in multiple sclerosis plaques could be visualized for the first time. The detection rate of chronic MS lesions surrounded by iron rims is significantly higher at 7T than at 3T, and

Partners can attain optimal outcomes in research and translational medicine that will ultimately benefit the patient by improving diagnoses and enabling noninvasive monitoring of different treatment regimens.

their presence is associated with an increase in volume over several years, which corresponds to slowly expanding MS lesions [5]. This noninvasive follow-up of patients with slow-progressing MS is of great interest to the pharmaceutical industry for evaluating drug efficacy. High-resolution MR spectroscopic imaging has become feasible at 7T, which enables the additional mapping of pathological processes in MS on a biochemical level and reveals even well-delineated (sub)cortical MS lesions down to ~3 mm in regions that are inconspicuous on conventional MRI [6]. Regions of myo-inositol (mIns) were often larger than on FLAIR and NAA maps, suggesting that an increase in mIns may provide an earlier imaging biomarker for neuroinflammation or lesion development than with conventional MR. A further improvement is patch-based super-resolution (PBSR), an up-sampling method shown to work better than standard interpolation techniques for MRSI maps. PBSR uses imaging data to search for similar neighboring voxels during up-sampling for increased fidelity. The first application of PBSR to glioma measurements, reaching an in-plane-resolution of less than 1 mm, provided better resolution of tumor metabolism than ever before [7]. The article by Hyunsuk Shim in this issue of MAGNETOM Flash describes how to make MRSI standard in clinical imaging. In vivo detection of gamma-aminobutyric acid (GABA) and glutamate (Glu), both major neurotransmitters in the human brain, benefits from the higher sensitivity and SNR at 7T compared to lower field strengths [8].

Optimized clinical operations

In MR mammography, high spatial and temporal resolutions are feasible simultaneously at 7T, which improves breast cancer detection rates, allows better differentiation between benign and malignant breast lesions, and may help to avoid unnecessary breast biopsies [9]. Multinuclear clinical applications such as sodium imaging can help evaluate the quality of repair tissue after different cartilage repair therapies and can monitor maturation over time [10]. Again, large pharmaceutical companies are now interested in these methods for monitoring the efficacy of newly developed cartilage regeneration drugs, and are increasingly accepting imaging as a primary endpoint for their clinical trials. With 7T, it is possible to perform proof-of-method studies on a small scale, which if successful can then be transferred to 3T for trials with larger patient cohorts. Sodium imaging provides insight into the negative effects of a systemic disease like type 1 diabetes mellitus on joint structures such as tendons and cartilage, even in young DM1 patients [11]. Finally, we were also able to demonstrate and quantify drug side effects on the composition of musculoskeletal structures, such as tendon weakening which may result in tendinosis and tears quantified by sodium imaging [12]. At 7T, ^{31}P spectroscopy can help to noninvasively differentiate between non-alcoholic benign liver disease and potentially progressive steatohepatitis; this was previously only possible with an invasive liver biopsy [13]. The article by Armin Nagel and colleagues describes his first experiences with X-nuclei on the clinical 7T MAGNETOM Terra system.

These results can only be achieved by close collaboration between the academic institution and the MR vendor. Both partners must have a clear vision, be prepared to take risks in a newly developing field, and be willing to join forces and share resources. In doing so, the partners can attain optimal outcomes in research and translational medicine that will ultimately benefit the patient by improving diagnoses and enabling non-invasive monitoring of different treatment regimens.

I hope you enjoy reading this issue and exploring the various aspects of precision medicine, healthcare delivery, and improved patient experience presented in the articles.

Siegfried Trattnig

References

1 Springer E, Dymerska B, Cardoso PL, et al. Comparison of Routine Brain Imaging at 3 T and 7 T. Invest Radiol. 2016; 51(8):469–82.
2 Springer E, Bohndorf K, Juras V, et al. Comparison of Routine Knee Magnetic Resonance Imaging at 3T and 7T. Invest Radiol. 2017; 52(1):42–54.
3 Stefanits H, Springer E, Pataraia E, et al. Seven-Tesla MRI of Hippocampal Sclerosis: An In Vivo Feasibility Study With Histological Correlations. Invest Radiol. 2017; 52(11):666–671.
4 Beisteiner R, Robinson S, Wurnig M, et al. Clinical fMRI: evidence for a 7T benefit over 3T. Neuroimage. 2011; 57(3):1015–21.
5 Dal-Bianco A, Grabner G, Kronnerwetter C, et al. Slow expansion of multiple sclerosis iron rim lesions: pathology and 7 T magnetic resonance imaging. Acta Neuropathol. 2017; 133(1):25–42.
6 Hangel G, Jain S, Springer E, et al. High-resolution metabolic mapping of gliomas via patch-based super-resolution magnetic resonance spectroscopic imaging at 7T. Neuroimage. 2019; 191:587–595.
7 Heckova E, Strasser B, Hangel GJ, et al. 7 T Magnetic Resonance Spectroscopic Imaging in Multiple Sclerosis: How Does Spatial Resolution Affect the Detectability of Metabolic Changes in Brain Lesions? Invest Radiol. 2019; 54(4):247–254.
8 Moser P, Hingerl L, Strasser B, et al. Whole-slice mapping of GABA and GABA+ at 7T via adiabatic MEGA-editing, real-time instability correction, and concentric circle readout. Neuroimage. 2019; 184:475–489.
9 Pinker K, Baltzer P, Bogner W, et al. Multiparametric MR Imaging with High-Resolution Dynamic Contrast-enhanced and Diffusion-weighted Imaging at 7 T Improves the Assessment of Breast Tumors: A Feasibility Study. Radiology. 2015; 276(2):360–70.
10 Trattnig S, Welsch GH, Juras V, et al. 23Na MR Imaging at 7T after Knee Matrix-associated Autologous Chondrocyte Transplantation Preliminary Results. Radiology. 2010; 257:175–84.
11 Marik W, Nemec SF, Zbýň Š, et al. Changes in Cartilage and Tendon Composition of Patients With Type I Diabetes Mellitus: Identification by Quantitative Sodium Magnetic Resonance Imaging at 7 T. Invest Radiol. 2016; 51(4):266–72.
12 Juras V, Winhofer Y, Szomolanyi P, et al. Multiparametric MR Imaging Depicts Glycosaminoglycan Change in the Achilles Tendon during Ciprofloxacin Administration in Healthy Men: Initial Observation. Radiology. 2015; 275(3):763–71.
13 Traussnigg S, Kienbacher C, Gajdošík M, et al. Ultra-high-field magnetic resonance spectroscopy in non-alcoholic fatty liver disease: Novel mechanistic and diagnostic insights of energy metabolism in non-alcoholic steatohepatitis and advanced fibrosis. Liver Int. 2017; 37(10):1544–1553.

We appreciate your comments.
Please contact us at magnetomworld.team@siemens-healthineers.com

Editorial Board

Review Board