Clinical MR Imaging
This is the third edition of this very popular general textbook on MRI, with the previous editions having been published in English and German in 1999 and 2003. Since the last edition, MRI advances and developments have continued to occur regularly and rapidly, with MRI continuing to be the most complex imaging technique available in medicine. At the same time, MRI has proven to be the single most useful imaging method for a whole host of diseases and organ systems. Hence the publication of the third edition of this very practical book now, in 2009, is very appropriate, timely, and welcome. It makes the reader up to date and has been revised extensively.

The three introductory chapters of the previous editions have been combined in a single chapter covering the principles of MR Imaging. This overview is followed by chapters on each of the major human organ systems with chapters on brain, spine, head and neck, MSK, abdomen, retroperitoneum, pelvis, chest, heart, angiography, breast, pediatric MRI, and whole-body MRI. All chapters have been extensively revised by including new figures. Most chapters have been re-written, many with new co-authors, broadening the scope of each individual chapter, and covering the new technical and clinical developments in these areas.

As with the first two editions, all the chapters are written by recognized authorities renowned for their subject expertise, and all are tied into a single, excellent, very readable volume by editors Peter Reimer, Paul Parizel, James Meaney, and Falko A. Stichnoth. The editors and authors are to be commended for achieving the proper balance of the technical and clinical aspects of MRI. The book is very practical, and is both comprehensive and concise. Every chapter is up-to-date with the latest techniques, and very well illustrated with key diagrams and case material. The entire book can be easily read in a few days, and at the same time held as a handy and authoritative reference text. Trainees, technologists, and especially practicing radiologists will find this an extremely useful book.

Walter Kucharczyk, MD, FRCPC

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When I was asked by the authors to write a foreword to the third edition of their acclaimed book *Clinical MR Imaging: A Practical Approach*, I was very honored and I immediately accepted. Indeed, I know the second edition well and use it extensively for teaching purposes. So I went to my bookshelf to look into it once more, now in more detail, but I couldn’t find it. Suddenly, I remembered lending it to one of my research fellows when he started working with magnetic resonance (MR) imaging. I told him that this was the best book for learning the basics in a comprehensive, practical fashion. But apparently this fellow liked the book so much that I never got it back! I decided to buy a new book, but was informed by the publisher that the second edition is completely sold out. Medical books that completely sell out in their second edition must have certain characteristics: high quality, practical approach, comprehensive overview, up-to-date information, and a strong feeling for clinically relevant developments. This describes this multi-author book perfectly.

Over the past 30 years since its introduction to medicine, MR imaging has developed into one of the most versatile tools of daily diagnostic imaging. However, the end of its technological advancement has by far not yet been reached. MR imaging is one of the most highly used imaging modalities in fundamental and translational research, while new clinical applications pop up almost on a weekly basis. These clinical applications reach from screening for breast cancer in high-risk patients, to morphologic and functional diagnosis of brain or cardiac diseases, to therapy monitoring and follow-up of arthritis. Especially in an area undergoing such a tremendous and rapid advancement, one might assume that a textbook like this one is not needed, and that practical knowledge can be better obtained by reading the newly published literature. I think the contrary is true: A comprehensive, practical overview of the established knowledge helps a lot more than studying confusing new results derived from recently developed pulse sequence modifications, in areas where a lot of studies are needed to establish the necessary clinical evidence. Those who are less interested in fancy new developments but rather are looking for practical explanations of established applications in all relevant parts of medicine will find this book particularly helpful.

Peter Reimer, Paul M. Parizel, James F. M. Meaney and Falko A. Stichnoth, the editors of *Clinical MR Imaging: A Practical Approach*, are well-known experts in the field of clinical MR imaging. Their affiliations with a university medical center, a large community hospital, and a private practice respectively guarantee that the book highlights all the different perspectives of clinical MR imaging from primary to tertiary care. The authors of the different chapters are the finest and most renowned experts in Europe in their respective fields. Most of them have been involved in major
new developments in MR imaging and have extensively contributed to the advancement of the technology as well as its clinical use. The European “flavor” of the book is especially recognizable in some of the described indications. High-quality figures illustrate extensively each of the applications, and a short overview of the relevant literature concludes each of the chapters.

I am firmly convinced that the third edition of this book will have the same success as the previous editions and will be soon sold out. So get ahold of it quickly or you will have to wait for the fourth edition.

Gabriel P. Krestin

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Magnetic resonance (MR) imaging has developed into the most versatile cross-sectional imaging method in clinical practice. Improvements in both hardware and sequences are broadening the scope of clinical applications with breathtaking speed. From the start MR gained an early foothold in neuroradiology and musculoskeletal radiology; however, recent developments have widened its application to include abdominal, cardiovascular, breast, chest and whole-body applications.

As a result of novel technical developments, MR imaging offers to medical practitioners a palette of high-quality anatomical imaging, and, more recently broader functional imaging applications. Diffusion-weighted imaging, a technique for the detection of early cerebral ischemia, is no longer regarded as a brain only study and offers advantage for anatomical and functional assessment of tumours outside the nervous system. The many paradigm shifts in MR imaging frequently present an obstacle not only to beginners who may find it difficult to get started while the goalposts are changing so rapidly, but also to more experienced users who find it hard to keep abreast of recent advances and new applications. Comprehensive information about all aspects of MR imaging can be found in many excellent textbooks and reference works, several of which have become encyclopaedic in scope and sheer volume, and examining the subject matter in such detail is beyond the scope of this textbook.

However, in recognition of the fact that routine diagnostic questions account for more than 90% of examinations in most departments, the editors and authors of this book, endeavoured to present a more clinically relevant approach. This lead to a practical protocol-based approach to the routine workflow in the MR unit, which can be streamlined considerably, which is increasingly critical in today’s economic environment. We have aimed to equip the reader with such information, to allow best use of MR technology and capability, based on our collective experience gleaned from years of cutting-edge clinical practice.

The third edition of this book thus offers practical guidelines for efficient and cost-effective MR imaging examinations in daily practice. The authors and editors have rewritten all chapters, included new techniques where appropriate, added new figures and replaced older ones, reflecting best clinical practice. Major changes include new chapters on whole-body imaging and on the technical background of MR imaging, a new subchapter on the GI tract within the abdominal chapter, a combined chapter on musculoskeletal MR, in addition to complete revisions of all other chapters.

As editors, we hope that this book will lead to a better practical understanding of MR imaging and improved appreciation of new sequences and protocols, which will
contribute to enhanced clinical problem solving. As such, we believe this book will continue to help beginners to advance their starting point in tailoring protocols and aiding more experienced users in updating their knowledge.

Karlsruhe, Germany
Edegem, Belgium
Dublin, Ireland
München, Germany

Prof. Dr. Peter Reimer
Paul M. Parizel
James F.M. Meaney
Falko A. Stichnoth
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Abbreviations

ADC  Analog to digital converter (in conjunction with data acquisition)
ADC  Apparent diffusion coefficient (in conjunction with DWI)
ASL  Arterial spin labeling
b  $b$-value in s/mm² indicative for the diffusion weighting
$B_0$  Field strength of the main magnetic field in Tesla (T)
$B_1$  Magnetic field component of an RF pulse
bEPI  Echo-planar imaging sequence with “blipping” phase encoding gradient pulses
bFFE  Balanced fast field echo sequence
BLADE  Data acquisition with a radial trajectory within k-space
BOLD  Blood oxygenation level dependent
bSSFP  Balanced steady state free precession sequence (trueFISP)
CASL  Continuous arterial spin labeling
ceMRA  Contrast-enhanced magnetic resonance angiography
CHESS  Chemical shift selective pulse
CISS  Constructive interference steady-state sequence
CNR  Contrast-to-noise ratio
CP  Circular polarization (in conjunction with transmitting and receiving coils)
CSF  Cerebrospinal fluid
CSI  Chemical shift imaging
CUBE  3D FSE imaging sequence with variable refocusing angle (SPACE)
DESS  Double-echo steady-state sequence
DRIVE  DRIVE sequence (“driving” the longitudinal magnetization)
DSC  Dynamic susceptibility contrast
DTI  Diffusion tensor imaging (illustration of directional diffusion)
DWI  Diffusion weighted imaging
DW-SE-EPI  Diffusion weighted spin-echo echo-planar-imaging sequence
EPI  Echo planar imaging
EPISTAR  Echo-planar imaging with signal targeting using alternating RF
ETL  Echo train length: number of phase encoded echoes used in a multi-echo sequence
FA  Fractional anisotropy
FAIR  Flow alternated inversion recovery
FFE  Fast-field echo sequence
FFT  Fast Fourier transformation
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<tr>
<th>Abbreviation</th>
<th>Description</th>
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<tr>
<td>FID</td>
<td>Free induction decay</td>
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<tr>
<td>FIESTA</td>
<td>Fast imaging employing steady state acquisition sequence</td>
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<tr>
<td>FISP</td>
<td>Fast imaging with steady-state precession sequence</td>
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<tr>
<td>FLAIR</td>
<td>Fluid attenuated inversion recovery</td>
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<td>FLASH</td>
<td>Fast low-angle shot sequence</td>
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<tr>
<td>fMRI</td>
<td>Functional magnetic resonance imaging</td>
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<tr>
<td>FoV</td>
<td>Field of view</td>
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<tr>
<td>FRFSE</td>
<td>Fast recovery fast spin echo sequence</td>
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<tr>
<td>FS</td>
<td>Fat saturation</td>
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<tr>
<td>FSE</td>
<td>Fast spin-echo sequence</td>
</tr>
<tr>
<td>FSPGR</td>
<td>Fast spoiled GRASS sequence</td>
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<tr>
<td>GBP</td>
<td>Global bolus plot</td>
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<tr>
<td>GMR</td>
<td>Gradient motion rephasing</td>
</tr>
<tr>
<td>GRAPPA</td>
<td>Generalized autocalibrating partially parallel acquisition</td>
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<tr>
<td>GRASE</td>
<td>Gradient and spin echo sequence</td>
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<tr>
<td>GRASS</td>
<td>Gradient recalled acquisition in the steady state sequence</td>
</tr>
<tr>
<td>GRE</td>
<td>Gradient echo sequence</td>
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<tr>
<td>GSP</td>
<td>Graphical slice positioning</td>
</tr>
<tr>
<td>HASTE</td>
<td>Half Fourier acquired single-shot turbo spin-echo sequence</td>
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<tr>
<td>HASTIRM</td>
<td>Half Fourier acquired single-shot turbo spin-echo sequence using inversion recovery and only the signal magnitude</td>
</tr>
<tr>
<td>HYPR</td>
<td>Highly contrained backprojection for time-resolved MRI</td>
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<tr>
<td>IR FSE</td>
<td>Inversion-recovery fast spin-echo sequence</td>
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<td>IR</td>
<td>Phase sensitive inversion-recovery sequence</td>
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<tr>
<td>IRM</td>
<td>Inversion-recovery sequence that utilizes only the magnitude</td>
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<tr>
<td>k-t BLAST</td>
<td>k-t broad-use linear acquisition speed-up technique</td>
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<tr>
<td>LAVA-XV</td>
<td>Volume interpolated sequence</td>
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<td>LOTA</td>
<td>Long time averaging</td>
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<tr>
<td>MEDIC</td>
<td>Multi-echo-data image-combination</td>
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<tr>
<td>MERGE</td>
<td>Synonym for MEDIC</td>
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<tr>
<td>MIP</td>
<td>Maximum intensity projection</td>
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<tr>
<td>MPR</td>
<td>Multi planar reconstruction</td>
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<tr>
<td>MP-RAGE</td>
<td>Magnetization-prepared rapid acquired gradient echo sequence</td>
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<td>MR</td>
<td>Magnetic resonance</td>
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<td>MRA</td>
<td>Magnetic resonance angiography</td>
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<td>MRCP</td>
<td>MR cholangiopancreatography</td>
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<td>MRS</td>
<td>Magnetic resonance spectroscopy</td>
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<tr>
<td>mSENSE</td>
<td>Modified SENSE</td>
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<tr>
<td>MT</td>
<td>Magnetization transfer</td>
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<tr>
<td>MTC</td>
<td>Magnetization transfer contrast</td>
</tr>
<tr>
<td>MTS</td>
<td>Magnetization transfer saturation</td>
</tr>
<tr>
<td>MTT</td>
<td>Mean transit time</td>
</tr>
<tr>
<td>MultiVane</td>
<td>Data acquisition with a radial trajectory within k-space</td>
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<tr>
<td>NATIVE</td>
<td>Gated sequences for nonenhanced MRA of the signal</td>
</tr>
<tr>
<td>PACE</td>
<td>Prospective acquisition correction</td>
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<tr>
<td>PASL</td>
<td>Pulsed arterial spin labeling</td>
</tr>
<tr>
<td>PAT</td>
<td>Parallel acquisition techniques</td>
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<tr>
<td>PBP</td>
<td>Percentage of baseline at peak</td>
</tr>
<tr>
<td>PC-MRA</td>
<td>Phase contrast MR angiography</td>
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Abbreviations

PD    Proton density
PD-W  Proton density weighted
PILS  Partially parallel imaging with localized sensitivities
PPA   Partially parallel acquisition
PROPELLER  Data acquisition with a radial trajectory within k-space
PSIF  A backwards-running FISP sequence
PWI   Perfusion weighted imaging
QUIPSS Quantitative imaging of perfusion using a single subtraction
RA    Relative anisotropy
RARE  Rapid acquisition with relaxation enhancement
rCBF  Regional cerebral blood flow
rCBV  Regional cerebral blood volume
RESTORE  RESTORE sequence (“restoring” longitudinal magnetization)
RF    Radio frequency
rMTT  Regional mean transit time
ROI   Region of interest
SAR   Specific absorption rate
SE    Conventional spin-echo sequence
SENSE Sensitivity encoding
sEPI  Spiral echo-planar imaging sequence
SMASH Simultaneous acquisition of spatial harmonics
SPACE RIP  -Sensitivity profiles from an array of coils for encoding and reconstruction in parallel
SPACE Sampling perfection with application optimized contrast by using different flip angle evolutions sequence
SPAIR Spectral inversion using an adiabatic RF pulse sequence
SPGR  Spoiled GRASS sequence
SPIR  Spectral inversion recovery sequence
SR    Saturation recovery sequence
SSD   Surface shaded display
SSFSE Single-shot fast spin-echo sequence
STEAM Stimulated echo acquisition mode
STIR  Short tau inversion recovery sequence
SVS   Single voxel spectroscopy
SWI   Susceptibility weighted imaging
T1    Tissue-specific spin-lattice relaxation time
T1-W  Contrast is weighted by the T1 relaxation time
T2    Tissue-specific spin-spin relaxation time
T2*   Relaxation time T2 plus additional dephasing mechanism (signal decay) due to local field inhomogeneities or chemical shift
T2-W  Contrast is weighted by the T2 relaxation time
TE    Echo time
TFE   Turbo field echo sequence
TFL   TurboFLASH
TGSE  Turbo gradient and spin-echo sequence
THRIVE Volume interpolated sequence
TIR   Turbo inversion recovery sequence
TIRM  Turbo inversion recovery sequence that utilizes only the magnitude of the signal
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<th>Definition</th>
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<tr>
<td>ToF-MRA</td>
<td>Time of flight MR angiography</td>
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<tr>
<td>TONE</td>
<td>Tilted optimized non-saturating excitation</td>
</tr>
<tr>
<td>TR</td>
<td>Repetition time</td>
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<tr>
<td>TRACE</td>
<td>Trace of the diffusion tensor (sum of the diagonal elements)</td>
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<tr>
<td>TRAPS</td>
<td>Transition between pseudo steady-state sequence</td>
</tr>
<tr>
<td>TREAT</td>
<td>Time-resolved echo-shared angiography technique</td>
</tr>
<tr>
<td>TRICKS</td>
<td>Time-resolved imaging of contrast kinetics</td>
</tr>
<tr>
<td>trueFISP</td>
<td>True fast imaging with steady precession</td>
</tr>
<tr>
<td>TSE</td>
<td>Turbo spin-echo sequence</td>
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<tr>
<td>TTP</td>
<td>Time to peak</td>
</tr>
<tr>
<td>turboFLASH</td>
<td>Fast low angle shot sequence with preceding inversion pulse</td>
</tr>
<tr>
<td>TWIST</td>
<td>3D time-resolved angiography with interleaved stochastic trajectories</td>
</tr>
<tr>
<td>VENC</td>
<td>Velocity encoding</td>
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<tr>
<td>VERSE</td>
<td>Variable-rate selective excitation</td>
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<tr>
<td>VIBE</td>
<td>Volume interpolated breathhold examination sequence</td>
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<tr>
<td>VIPR</td>
<td>Vastly undersampled isotropic projection imaging sequence</td>
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<tr>
<td>VISTA</td>
<td>3D TSE imaging sequence with variable refocusing angle (SPACE)</td>
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<tr>
<td>VR</td>
<td>Volume ratio</td>
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<td>VRT</td>
<td>Volume rendering technique</td>
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