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Preclinical MRI of the Kidney

Methods and Protocols

Edited by

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Preface

Preclinical MRI for Renal Health

Despite the fact that we are in an era of increased prevalence, incidence, and recognition of renal diseases, the current options for effective prophylactic and therapeutic regimens for kidney disorders are disappointingly sparse. A major obstacle is the inherent complexity of the pathophysiology in renal disease. Overcoming this requires immediate innovative action across multiple domains and requires new instruments that enable noninvasive diagnostics and monitoring of therapy during renal diseases. The upshot is that this also creates ever-increasing opportunities for discovery.

The development and validation of disruptive diagnostic approaches and strategies for early interception of renal disease and renoprotection can be brought on only with a deeper understanding of the underlying (patho)physiology. This underlines the urgent quest for emergent biomedical imaging techniques, customized for probing all stages of renal diseases. While many renal diseases involve defects at the molecular and cellular levels, these manifest themselves at the scale of the organ system. The unique function of biomedical imaging is to monitor all these levels simultaneously, connecting the view of biologists with that of clinicians *in vivo*. This asks for approaches that are noninvasive, ubiquitous, and applicable both preclinically and clinically—this is the forte of magnetic resonance imaging (MRI). An increasing body of evidence indicates that MRI biomarkers have a high potential for complementing and improving acute and chronic renal disease management. MRI is a versatile technique, and a host of functional MRI methods have emerged that are sensitive to pathophysiological changes associated with renal hemodynamics, oxygenation, fibrosis, inflammation, and microstructure. To better connect MR imaging markers with (patho)-physiology, MRI needs to be benchmarked and calibrated with integrative physiological measurements which include the use of quantitative invasive probes. Due to the enormous technical challenges involved, renal MRI biomarkers remain woefully underused in preclinical research and in clinical practice. These scientific and technical issues constitute a substantial barrier *en route* to the standardization and broad application of renal MRI.

The purpose of this book is to overcome these roadblocks by promoting an open-access collection of protocols and comprehensive recommendations for preclinical renal MRI, to be employed in translational research. The book provides answers to the common questions regarding how renal MRI technologies emerging from the research community can be translated into open-access, ready-to-go toolboxes that can be applied to human patients in a way that is standardized, highly reproducible, and harmonized across centers, with the goal of combating renal disease by substantially slowing its progression and preventing kidney injury.

With this "*from the community, to the community*" approach, the book is designed to enhance training in renal MRI sciences, to improve the reproducibility of renal imaging research, and to boost the comparability of renal MRI studies. With this mission, the book promotes an entirely unique opportunity for developing advanced *in vivo* renal phenotyping, diagnostic imaging, and therapy guidance as a link to stratified medicine. The clinical implications of this relate to a broad spectrum of physiology, nephrology, radiology,

cardiology, and other associated fields of basic science and clinical research targeting renal and cardiorenal diseases.

The chapters covered in this book are interdisciplinary in nature and bridge the gaps between physics, physiology, and medicine. The contributions are provided by leading international experts and hands-on scientists and serve as a foundation to substantially boost the development of renal imaging tools, which will increase the efficacy of diagnostics, promote the identification of new therapeutic targets and options, drive explorations into novel renoprotective strategies, and lead to enhanced prophylactic regimens. To meet this goal, the book provides chapters on the fundamental principles, detailed experimental protocols and guidelines for data analysis, to successfully unlock the full potential of renal MRI. At the same time, the book promises to help nurture a new generation of researchers with the high potential needed for the development of next-generation renal imaging technology, by addressing some crucial educational gaps.

The pace of discovery of preclinical MRI is heartening, drawing in new talent and driving the transfer of results into novel preclinical applications and into the clinical arena. The remaining challenges must be faced openly via collaborations between forward-thinking researchers, application scientists, clinicians, and the general readership of this book. These collaborations should be interdisciplinary, inter-institutional, and international, as exemplified and spearheaded by imaging networks. A prominent example of this is the renal imaging initiative PARENCHIMA, a community-driven Action of the COST (European Cooperation in Science and Technology) program of the European Union, which aims to improve the reproducibility and standardization of renal MRI biomarkers. Only because of the truly interdisciplinary nature of this work, and the essential role that having many types of expertise in close interaction has played, we got this far.

This book lives up to this mission by providing a comprehensive overview and guidance on preclinical MRI. It is intended to take this approach to the next level and to put extra weight behind finding a solution to the remaining problems in renal imaging research. With this mission, the reader will learn to make sense of the terrain we currently inhabit and to better interpret the images of the kidney that we produce using sophisticated preclinical MRI and data analysis protocols. Inevitably, there will be breakthroughs and surprises when you place next-generation imaging technologies and this book into the hands of highly creative interdisciplinary teams. However, this will only happen if we recognize that moving into the next generation of renal imaging technology is more than just a matter of buying equipment, installing it, and then trying to operate in "core facilities" where budgetary considerations, and not scientific goals, dominate. The ultimate potential of preclinical renal MRI is far greater; all that is required is the imagination to apply it, following the chapters in this book as a roadmap. We hope that the book will convey the seeds of this vision and inspire you—as it has us—to become pioneers in this amazingly promising area.

With this perspective, we are grateful to all the authors for their outstanding work, passion, dedication, and enthusiasm to drive this assembly of recommendations and open-access protocols on preclinical MRI home. We all succeeded thanks to the sheer power and momentum of interdisciplinary collaboration and teamwork. You made and make the difference. Thank you.

Berlin, Germany

Thoralf Niendorf
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Part V Protocols for Advanced Analyses

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