# Diffusion-Weighted MR Imaging of the Brain

Moritani · Ekholm · Westesson

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# Foreword

Few advances in MR imaging have had the impact that diffusion-weighted imaging (DWI) has had in the evaluation of brain. From the time of the early descriptions by LeBihan and colleagues of the ability to image and measure the micromovement of water molecules in the brain to the present time, diffusion imaging and its derivatives have made an impact in the evaluation of multiple disease processes, primarily in ischemia, but also in other conditions of the brain. In most medical centers diffusion imaging is no longer considered a sequence to be used in special circumstances but rather it is employed as part of routine MR imaging of the brain. Because the information derived from diffusion measurements can improve our understanding of pathologic processes and can influence patient care, knowledge of the principles and applications of DWI is critical.

It is therefore of great interest that the group from the University of Rochester (Drs. Moritani, Ekholm, and Westesson) have assembled under one cover a collection of material which covers all the clinical aspects of diffusion-weighted imaging. Those who have attended recent meetings of the ASNR know the quality of the exhibits and presentations which have come from this group. They, early on, demonstrated the wide spectra of diseases which can cause restricted diffusion and they warned us of mimickers of infarction and ischemia.

In this richly illustrated volume the authors take the reader from the basic principles of DWI, through the pulse sequences used, to mathematical concepts behind the derivation of apparent diffusion coefficients. Following explanations of the different types of edema which can effect the brain and the appearance of DW images, this book allows the reader to see the variety of conditions which alter diffusion, including infarction, hemorrhage, cerebral infections, degenerative neurologic disorders, white matter diseases, toxic/metabolic disorders, and tumors. As one can easily see from the table of contents, the authors have systematically covered all major areas of neuroradiology. This will allow cross-referencing to problematic cases which one may encounter. Additionally, knowledge of what represents a normal brain in adults and in the developing brain along with an explanation of artifacts seen in DWI makes this a valuable book. It is noteworthy that the authors have chosen to abundantly illustrate the clinical material, drawing on pathologic correlations in a number of areas.

I believe that this book will benefit not only those who deal routinely with neuro-MR imaging, but also those who want to establish a basis for understanding of diffusion images in the hope of taking these principles of diffusion further into more exotic areas of neuroimaging such as white matter tract mapping with diffusion tensor imaging, analyzing alterations in highly organized structures with fractional anisotropy, or delving into macromolecular alterations with ever-higher b values. The authors are to be congratulated for putting their considerable experience together in this form, and I am sure that the collection of cases herein will serve to educate not only those who are just entering the clinical neurosciences, but also those who daily use diffusion imaging to arrive at a proper clinical diagnosis.

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# Preface

This book is the result of many years of clinical and academic interest in diffusion-weighted MR (DW) imaging of the brain. Researchers and clinicians at the University of Rochester started to collect DW images of a spectrum of abnormalities affecting the brain immediately after this technique became available. Several case series with clinical and radiographic correlations have been presented at the annual meetings of the American Society of Neuroradiology and the Radiological Society of North America via posters and scientific reports. Over time it became quite clear that we had a collection of DW images representing the majority of conditions that affect the brain and we felt a need to put them all together under one cover.

MR imaging has evolved dramatically since its introduction into clinical work in the mid-1980s. Looking back, there are several major steps that took MR imaging of the central nervous system to the next level. One of the first steps was the introduction of the clinical usefulness of contrast agents. Other steps were the development of fat suppression techniques, fast spin echo imaging, and, more recently, the development of a clinically useful DW imaging technique. DW imaging has revolutionized the imaging diagnosis of acute infarction in the brain. It is, however, quite clear from the series of cases shown in this book that DW imaging is useful for many other conditions. The time it takes to obtain a DW image is so short that in many institutions it is now being used as a routine part of any MR imaging of the brain.

The initial chapters on principles of DW imaging, normal DW appearance, and pitfalls and artifacts provide the bases for understanding DW imaging. This technique is complex and is associated with many pitfalls and artifacts. The following chapter on brain edema provides the basis for understanding the pathophysiology of signal alterations in DW images related to various pathological conditions. The images are correlated to corresponding neuropathologic slides and aid the understanding of the DW imaging representation of various types of brain edema. Chapters 5–13 cover DW imaging characteristics of different pathologic conditions and in Chap. 14 (pediatrics) we have collected DW images of pediatric conditions.

The book is organized according to major disease categories. This brings structure to the book, but is not optimal for the clinician sitting in front of a set of images and wondering what they might represent. For that reason we have a summary chapter entitled "How to Use This Book" (Chap. 15), which is organized from the opposite perspective. Thus, in Chap. 15 we have started with DW images and grouped them according to imaging characteristics. In each table we have listed differential diagnoses for each specific set of DW imaging characteristics and added thumbnail images with references to the corresponding chapters. The clinician can go directly to Chap. 15, determine the signal on the DW imaging, combine it with the T2 and ADC signal characteristics, and get a list of the conditions that match these imaging characteristics. The thumbnail images, the reference to corresponding chapter and knowledge about the patient's clinical presentation should allow the clinician to formulate a relatively narrow differential diagnosis for most clinical conditions. We think that this "reversed" chapter will make the book very useful for everyday work with DW imaging of the brain.

We are grateful for many pathological slides and fruitful discussions with Barbara Germin, MD, Department of Pathology, University of Rochester. We acknowledge the case contribution from the Department of Radiology, Showa University, Japan, collected during the primary author's time at Showa University. We would also like to thank Masahiro Ida, MD, Department of Radiology, Ebara Municipal Hospital, Japan; Minoru Morikawa, MD, Department of Radiology, Nagasaki University, Japan; R. Nuri Sener, MD, Department of Radiology, Ege University Hospital, Turkey; and Ryutarou Ukisu, MD, Department of Radiology, Showa University, Japan, all of whom contributed case studies. Our deepest gratitude goes to Ms Margaret Kowaluk and Ms Theresa Kubera, Med-

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We want to thank the editorial staff at Springer-Verlag, without whose guidance, skills and knowledgeable advice this book would not have become a reality. We would also like to thank our colleagues, fellows and coworkers at the University of Rochester. Finally, but not least, we thank our families for giving us the time to complete this project.

It is our hope that our readers will find this book on "Diffusion-Weighted Imaging of the Brain" instructional and clinically useful.

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