Preface

It is with tremendous enthusiasm and excitement that we introduce the book *Magnetic Resonance Angiography: Principles and Applications* to those who are interested in and involved with the ever-expanding field of magnetic resonance angiography (MRA).

Vascular disease remains to this day the central cause for many serious clinical conditions, such as stroke, myocardial infarction, and peripheral arterial disease, each of which can precipitate further downstream complications, which can ultimately lead to serious morbidity and death in many individuals. While huge progress has been made to develop novel therapies for vascular pathologies, such as minimally invasive endovascular stents and stem cell therapies, much of these approaches still depend on an accurate depiction of the appearance and extent of abnormalities within the blood vessels.

The original gold standard for diagnosing vascular disease was catheter-based digital subtraction angiography, which of course is invasive for the patient and can result in significant complications, albeit rare with current technology. The concept of inserting a needle directly into an artery so that iodinated contrast can be injected rapidly to opacify blood vessels under X-ray visualization will seem barbaric to readers of this textbook. In fact, it was not long ago that the accepted standard for diagnosing peripheral vascular disease was translumbar aortography, where the abdominal aorta was directly accessed percutaneously for diagnostic angiographic purposes. While such diagnostic techniques seem prehistoric and dated in the modern era, it is also a testament to how much progress has been made in the area of noninvasive vascular diagnosis that we have this attitude.

Given the invasive alternatives, much effort has been spent on developing alternative noninvasive diagnostic techniques for assessing vascular disease. One of these tools, Doppler ultrasound, is used in routine clinical practice today to assess conditions, such as carotid artery stenosis and peripheral vascular disease. Ultrasound has the advantage of being noninvasive, cheap, and easily portable; however, it is most useful for superficial vessels, not having the penetration to image deeper structures, such as the intracranial vasculature or pulmonary circulation. Computed tomography (CT) is one of the most common diagnostic tools used today in medicine and can also be employed to image the vasculature. CT has achieved particular success with the recent development of multidetector scanners that allow rapid acquisition speeds at spatial resolutions that approximate digital subtraction angiography. While CT is quick and easy to operate, two major drawbacks include exposure to ionizing radiation and the requirement of injected potentially nephrotoxic-iodinated contrast for vessel opacification. Finally, magnetic resonance imaging (MRI), which is also used in all areas of medicine today, is ideally suited for imaging the vasculature. It is a noninvasive imaging tool too; however, in contrast to CT and catheter-based angiography, it does not use ionizing radiation and gadolinium, which is used as the contrast agent, is relatively nontoxic compared to iodinated agents. While MRI also has some disadvantages, such as not being able to scan patients with devices, such as pacemakers, it is the only modality that can combine anatomic depiction with functional assessment in the same study.

MRI emerged as a vascular imaging tool about 30 years ago with the discovery of time-of-flight (TOF) imaging, where it became apparent that, as blood flowed through an external magnetic field, it emitted a signal that could be used for imaging purposes. TOF was the original noncontrast MRA technique; however, scan times were long and images were plagued by flow artifacts that could result in misdiagnosis. The technique has benefited from acceleration strategies developed over the years and is still used routinely in the intracranial circulation. The field of MRA really took off in the 1990s with the development of contrast-enhanced MRA. Contrast-enhanced MRA relied on an intravenous injection of a gadolinium-based extracellular contrast agent which, when imaged with a T1-weighted gradient echo pulse sequence, produced bright images of the blood vessels with suppression of the background tissues. The principal impact of contrast-enhanced MRA was that it produced images that were similar to conventional angiograms in very short periods of time. Much of the development in the field of MRA over the following decade focused on improving acquisition speed and spatial resolution for contrast-enhanced MRA. More recently, a condition known as nephrogenic systemic fibrosis (NSF) was described and its cause was linked to patients with renal dysfunction who were exposed to high doses of gadolinium. A lot more is known about NSF now and the condition has nearly been eliminated with better screening of patients and using lower doses of gadolinium. One less talked about consequence was that the field of MRA diverted its attention away from contrast-enhanced MRA to the development of noncontrast MRA techniques. The result was the development of a myriad of new techniques over the last few years that has become confusing to practicing clinicians and scientists in the field.

Magnetic Resonance Angiography: Principles and Applications is designed to bring together into a single textbook all of the different MRA techniques, both contrast-enhanced and noncontrast, current contrast agents and implications for NSF, and strategies for applying these techniques in different clinical situations. The book is targeted to physicists, physicians (particularly those specializing in imaging), MRI technologists, residents, fellows, and students, both doctoral and postdoctoral. The book does not claim to have all of the answers and reflects a snapshot of current thinking in the field. Already there are new developments on the horizon. However, we hope to be able to provide a concrete basis for comprehending current MRA techniques and the clinical protocols in which they are applied so that new techniques can be more easily understood.

With this objective in mind, we have divided the textbook into two parts. Part I (Chaps. 1–16) is focused on MRA techniques and part II (Chaps. 17–29) is focused on clinical applications.

Part I begins with a review of MRI physics as it pertains to MRA. There are chapters devoted to all of the main MRA techniques, including contrast-enhanced MRA, time-of-flight, and phase contrast. There are several chapters devoted to newer noncontrast MRA techniques. A couple of specific areas, such as time-resolved angiography and coronary MRA are addressed independently. We have also attempted to describe in more detail-specific topics, such as high-field MRA, susceptibility-weighted imaging, acceleration strategies, such as parallel imaging, vessel wall imaging, targeted contrast agents, and low-dose contrast-enhanced MRA.

Part II encompasses all of the clinical applications for MRA. Each chapter is divided into an initial "techniques" part, which describes the MRA techniques and protocols for that disease and vascular territory, and an "applications" part, which describes the pathology and imaging findings relevant to the disease state being discussed. There may be some repetition of techniques previously described in part I, although not with the same degree of detail. It is hoped that the techniques and protocols discussed will provide a foundation for the reader to develop his/her own protocols. We have deliberately avoided providing "canned" protocols, which may be somewhat restrictive given the numerous MRA techniques currently available. The "applications" part is designed to provide a comprehensive description of different pathologies together with MRA imaging findings. This should be particularly useful to physicians in practice, residents, and fellows in training. We have devoted specific chapters to NSF and its implications for contrast-enhanced MRA, MRI contrast agents, and newer topics, such as interventional MRI.

Finally, we would like to thank all of the contributors to this book, without whom this text would not be possible. Each author is a highly respected expert in the field of MRA and this book would not have been feasible without their contribution and dedication. We would like to thank all our colleagues in the MRI community whose inspiration, support, and friendship have been invaluable. We would specifically like to thank our respective mentors, Dr. Paul Finn, MD, and Dr. Charles Mistretta, PhD, whose past and ongoing support has provided guidance and encouragement for many years. We would like to thank Springer for bringing this book to fruition, specifically Jennifer Donnelly and Frances Louie, whose patience and effort have been immeasurable.

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