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Chapter 1

Introductory Chapter

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While early works on MRI focused on hardware and software developments, and the understanding of the biophysical principles, physiological, and pathophysiological phenomena that underlie MRI/NMR, in later years, efforts targeted improvements in acquisition speed, enhancement of image quality based on signal-to-noise-ratio benefits, multinuclear imaging, and the introduction of quantitative imaging/spectroscopy of metabolic, perfusion, and functional responses. Concerted parallel efforts targeted improvements in image quality through basic and advanced image processing techniques, capitalizing on advances in signal and digital image processing.

Scientific direction was strategically steered toward molecular imaging and personalized medicine in the early 2000, when focus groups at the National Institutes of Health (NIH) formulated scientific funding policies. Correspondingly, despite the inherent biophysical limitations of the phenomenon of NMR/MRI, the last 15 years have evidenced tremendous progress in breaking barriers toward molecular and intracellular imaging, synergistic or in competition with optical, positron-emission, and/or computer tomography.

In his chapter, Dr. Neubauer presents a succinct overview of the biophysical principles that govern spectroscopy and imaging of nuclei-other-than-protons, including sodium, potassium, and chlorine, and the ionic interactions with proteins. The chapter also extends to phosphorus and its value in the study of cellular metabolism and pH, and to the study of oxygen consumption. The study of ^{13}C techniques and novel MRI bioreactors are briefly introduced at the end of the chapter.

On the forefront of ^{1}H MRI, Drs. Samyn and LaDisa present an overview of computational fluid dynamics (CFD) modeling approaches based on MRI of large vessels. Phase contrast techniques were introduced in the late 1980s and early 1990s, work to study fluid flow, work among others that was independently pioneered by Drs. Dumoulin, Moran, Pelc, Firmin, and Mohiaddin. Tremendous advances have been documented ever since, especially for the study of large vessels, valvular disease, and cardiac chamber flow patterns. The high-resolution

nature of ^{1}H MRI has allowed the construction of accurate anatomic 3D models that have been used in conjunction with computational flow dynamic techniques to provide accurate estimation of flow patterns in health and disease. Estimation of quantitative biomarkers, such as the wall shear stress, became successful through fluid-structure interaction modeling, ultimately dependent on material tissue properties and the constitutive law dependence. Such biomarkers became increasingly important since they correlated with inflammation and atherogenesis. Drs. Samyn and LaDisa present a comprehensive overview of CFD-based approaches for the estimation of WSS in cardiovascular disease (acquired and congenital), and the assessment of helical flow patterns and their benefits. More importantly, the discussion is extended to atherosclerosis in pediatric and in congenital heart disease.

In addition to cardiovascular disease, MR-based modeling has also been extensively applied in cerebrovascular applications, including functional MRI (fMRI). Dr. Lee introduces a Bayesian spatial-temporal model to capture the spatial dependence of brain-activated voxels. The sparsity of the proposed model leads to an increased computational efficiency. It is validated through a simulation and actual fMRI data paradigms.

Image processing has been integral to MRI since its inception. Texture analysis has emerged in the 1960s following the introduction of mathematical frameworks for non-orthogonal reconstruction schemes, including the wavelet algorithm. In the clinic, interest for texture analysis intensified in the early 1990s, particularly for breast cancer diagnosis. Dr. Larrozal and colleagues present a comprehensive overview of the progress of the field since its early days. The approach is modular and streamlined, and is presented in terms of the steps of MRI acquisition, regional image definition, pre-processing, feature extraction, and classification. The future evolution of this field targets clinical applicability, once reproducibility accuracy has been achieved, based on multicenter, international studies.

Collectively, in the effort to assess cellular and organ function and dysfunction using MRI-derived methodologies, the work presented in this book attests to the tremendous strides and accomplishments achieved thus far and projects to future directions aiming to attain translation in the clinic.

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