Chapter

Introductory Chapter: Magnetic Resonance Imaging in Internal Medicine

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1. Introduction

In this book, the authors present the current trends in the development of magnetic resonance imaging (MRI) from the physical basics till the informative value in the clinical medicine. There is detailed information about the MRI in cardiovascular and pulmonary diseases, the newest contrast agents, and the relation between MRI and radiation therapy. Since its introduction due to the absence of ionizing radiation and higher sensitivity to many pathological conditions, the use of this imaging modality has increased in the recent years. The current chapter is dedicated to the role of MRI in the diagnostic medicine in general and introduction into the most significant and definitive imaging modality in the daily practice.

Magnetic resonance imaging (MRI) is a nonionizing imaging modality that uses the body's natural magnetic properties (imaging of protons) to produce detailed images with excellent anatomical details and exquisite, unmatched soft tissue contrast images from any part of the body [1].

The multiplicity of measurable MR parameters, including proton density, relaxation times, blood flow, chemical shift, diffusion, perfusion, and paramagnetic contrast agents provides unprecedented opportunities to explore morphology, pathology, physiology, and biochemistry [2].

MRI diagnoses diseases by identifying the content and distribution of hydrogen protons in the water molecules in different tissues and lesions. MRI may be effective to improve the specificity and accuracy of diagnosis and reducing the false positive rate [3].

MRI has been used in a number of nonneurologic indications, namely, spine, musculoskeletal, cardiac, hepatic, biliary, pancreatic, adrenal, renal, breast, and female pelvic imaging [4].

Cardiac magnetic resonance imaging (CMRI) is an imaging modality that can accompany the diagnostic algorithms in multiple clinical applications. It includes not only functional, but also anatomical and morphological assessments that allow ventricular and valvular functions at once to be evaluated, as well as characterization of metabolic function and perfusion. Identifications of structural assessment could be provided in multiple cardiovascular diseases like cardiomyopathies, congenital abnormalities, myocarditis, pericardial effusions, benign and malignant cardiac tumors, or congenital vascular diseases [5]. The strengths of CMR lie in its ability to comprehensively image cardiac anatomy, morphology, functions, perfusion, viability, and physiology, and the assumed information can be analyzed exactly and on time using a wide field of view of surrounding vascular and non-cardiac organs [6].

The clinical indications for every MR investigations, possible pitfalls and the challenges faced in spine imaging because of anatomical and physical constraints will be discussed. The basics of advanced MRI techniques are cerebrosopinal fluid flow, diffusion, diffusion tensor imaging (DTI), dynamic contrast-enhanced T1-weighted perfusion, MR angiography, susceptibility-weighted imaging (SWI), functional imaging (fMRI), and spectroscopy [7]. Magnetic resonance imaging (MRI) plays a leading role in evaluating and detecting spinal trauma. MRI is not only a diagnostic tool in spinal trauma, but also a prognostic predictor. It is possible to predict the neurological outcome of the patients with different cord abnormalities [8].

The pulmonary MRI is also an important step in the development of the diagnostic imaging. In the past, it was taught as useless or not enough informative, because of the insufficient appearance of the lung parenchyma. In the last years, it is recommended in multiple clinical indications including the lungs, pleura, hemidiaphragms, mediastinum, etc. In addition to this, MRI is preferred because of complete absence of ionizing radiation, especially for children and young or pregnant patients.

Magnetic resonance imaging (MRI) may be considered as the preferential imaging study in specific clinical conditions like cystic fibrosis and acute pulmonary embolism, because of additional functional information on respiratory functions and regional lung perfusion [9]. At the same time, the image resolution of MRI is superior than thin-slices MDCT. So, MRI plays an important role for functional imaging in patients with interstitial and bronchial lung diseases. The capability of MRI to distinguish and describe different inflammatory pulmonary conditions using different tissue signal weighting could be used in the planning of the treatment.

Functional MRI allows measurements of perfusion, blood flow, ventilation, gas exchange as well as respiratory motion and mechanics. This could be explained with the nonionizing nature of the imaging modality, which enables regular surveillance in order to monitor therapy during clinical trials or a daily clinical practice [10].

The MRI of the chest offers a noninvasive possibility to characterize mediastinal lesions, especially according to their etiology and the involvement of surrounding tissues and organs. The intravenous administration contrast mediums provide more information than CT in tissue characterization [11].

The introduction and the use of these diagnostic modalities in a multiparametric fashion enables to better characterize mediastinal structures, for example, thymic epithelial tumors, accurate assessment of the invasion of adjacent organs and also it is extremely sensitive in the differential diagnosis of pathologic lymph nodes and metastasis [12].

Breast MRI is a modality that is progressively integrated into the daily clinical practice. Diagnostic criteria are mainly based on the American College of Radiology's BI-RADS magnetic resonance imaging categories [13]. Breast MRI is an important new study in the diagnostic algorithms for the detection and reporting of breast carcinoma. Understanding the evidence-supported benefits and potential harms of breast MRI is important to ensure the appropriate utilization of this medical resource [14].

Another important use with increased informative value in the recent years is abdomen MRI, especially in oncology, where the patients have unique challenges and opportunities. The detection and characterization of a focal liver lesion require a difference in signal intensity between the lesion and the adjacent liver parenchyma. The administration of contrast mediums is very important to accentuate the inherent differences in liver-lesion signal intensity [15].

Traditionally, T2-weighted MRI sequences are commonly used to provide structural information on the anatomy of the pancreatic ductal system and lesions. MR cholangiopancreatography (MRCP) that use heavy T2-weighted sequences has been widely applied as noninvasive alternative to endoscopic retrograde cholangiopancreatography (ERCP) for biliopancreatic duct system evaluation [16].

Magnetic resonance imaging techniques are increasingly performed to evaluate renal function and injury. These include perfusion, diffusion, and blood oxygenation level-dependent (BOLD) imaging [1–3]. Because functional, molecular, and cellular changes precede anatomic changes, functional MR imaging enables the early detection of renal disease as well as improved understanding of disease pathogenesis that could facilitate the development of better treatment options and improve patient prognosis [17].

Similar to CT in MRI are used 3D or 4D reconstructions in the three main planes to improve the quality of the images.

3D T2-weighted MRI is increasingly utilized for pelvic disease in both gender, including imaging of rectal cancer, prostate cancer, anorectal fistulas, etc. This relative rapid modality offers better soft-tissue visualization of the pelvic organs including lymph nodes and blood vessels, with potential for more widespread clinical use [18].

MRI has traditionally been used for neurologic indications, including brain tumors, cerebrovascular diseases (strokes), infections (encephalomyelitis), and congenital abnormalities. It has far-reaching real and possible clinical applications. Its usefulness has been best explored and realized in the central nervous system, especially the posterior fossa and brain stem, where most abnormalities are better identified than with computed tomography [19].

Magnetic resonance imaging (MRI) of brain diseases provides excellent anatomical details—location, size, distribution, signal characteristics and also reveals functional information about vascularity, brain edema, and the preserved brain tissues [20].

Significant role for the development of MRI has the use of contrast agents. It increased the quality and diagnostic capabilities.

Strategic localization of the agent can regionally change the tissue properties and result in preferential enhancement. MRI is unique among diagnostic modalities because it uses more than one intrinsic property of the tissue being imaged. Gadolinium-based MRI contrast agents alter one or more of their physicochemical properties dynamically when interacting with their surrounding tissues environment [21].

The current trends in MRI also include the use of nanoparticles as contrast agents. Multiple nanoparticles and complexes have been studied as MRI contrast mediums, and several formulations have been approved for clinical use in the practice and clinical trials. These contrast agents are formed either of transition and lanthanide metals or of iron oxide nanoparticles and ferrite nanoparticles. MLPs can be carefully manipulated in their composition to incorporate cationic lipids, fluorescent-lipid conjugates, targeting ligands, drugs, and PEG, containing all in a single nanosystem [22].

The last chapter of the book is dedicated to the relation between MRI and the radiation therapy. It assists successfully the detection of the exact diagnosis and could be in many cases the definitive modality for the planning of radiation therapy procedures.

Magnetic resonance imaging provides unique advantages in comparison with computed tomography (CT): added contrast information that can improve segmentation of the areas of interest, motion information that can help to better target and deliver radiation therapy, and posttreatment outcome analysis to better understand the biologic effect of radiation [23].

The implementation of MRI has a number of challenges with a balance achieved between optimal image quality and minimal geometric distortion. This process required close collaboration between MRI radiographers and radiation therapists with their differing skill sets [24]. Nowadays in practice, there is an increase in 3D and 4D MRI techniques [25].

In conclusion, we can definitely say that the optimization and development of MRI including the widespread use of contrast agents is the main investigation for structural and functional changes in the human body. The characterization of tissues, organs, and systems can be approached by multiple ways using MRI and this imaging modality has the highest achievable resolution and informative value. In our future books, we hope to complete the current scientific information with new chapters about MRI of the abdominal organs, central and peripheral nervous system, and musculoskeletal diseases.

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