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Magnetic resonance imaging in personalized medicine

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Continued biomedical advances and increased demands on quality health care have led to a new era of personalized medicine—a concept of medicine that uses specific information to an individual to help diagnose disease, plan treatment, assess treatment efficacy, and/or predict prognosis. This concept has evolved from the idea of "patient-centered care", which intends to shift the focus of health care from diseases to patients (Abujudeh et al., 2016). Medical imaging is essential in the practice of modern medicine, and its role in personalized medicine has never been greater. In particular, magnetic resonance (MR) imaging—a versatile and growing medical imaging modality—is at the forefront leading the transformation from traditional practice to personalized medicine. In 2001, a survey of leading physicians ranked MR imaging as well as CT scan as the most important medical innovations since 1980s (Fuchs et al., 2001). Over the past four decades, MR imaging has shown an explosive growth and become the modality of choice for assessment of the central nervous system, abdominal and pelvic organs, musculoskeletal system, and beyond, due to its superb soft tissue contrast, absence of ionizing radiation, and ability to probe not only anatomic abnormalities but also the underlying function, physiology, and metabolism by using a battery of techniques, such as diffusion and perfusion imaging. The combination of anatomic and functional information on an individual patient is crucial to providing personalized disease diagnosis and enabling personalized disease management. Moreover, MR imaging yields a large number of quantitative and semi-quantitative parameters and/or biomarkers, contributing considerably to the delivery of precision medicine to individual patients. This issue contains six examples to show the diverse roles that MR imaging can play in the practice of "personalized medicine". These examples include quantification of functional MR imaging, clinical efficacy of conventional MR imaging, outcome studies enabled by MR imaging, and computer-aided analysis and diagnosis based on MR images. Taken together, these studies not only provide a snapshot of the present development of MR imaging in personalized patient management, but also point to several future directions in potential clinical translations.

Functional MR imaging allows visualization and/or quantification of biological functions *in vivo*. Over the past few decades, multiple functional MR techniques have been developed, such as neurofunctional imaging based on blood oxygen-level dependent contrast, diffusion imaging, and perfusion imaging. Among these techniques, diffusion-weighted imaging (DWI) measures water diffusion process in tissues and is widely used clinically to probe tissue microstructural alterations associated with disease progression and regression. Perfusion imaging contains a number of techniques relying on either endogenous contrast (e.g., the arterial blood) or exogenous contrast (e.g., gadolinium-based contrast agents). Among the perfusion imaging techniques, dynamic contrast-enhanced (DCE) MR scan is par-

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ticularly useful to evaluate tissue permeability and vascularity that are important in characterizing neoplastic tissues. Quantification of functional MR imaging results can help identify abnormal tissues that are otherwise undetectable by conventional MR imaging. Additionally, the severity of the abnormal pathophysiology can be assessed more accurately, concisely and reliably by means of quantification as compared to the conventional qualitative approach that has been used in radiology practice for over a century. In the article written by Jiang T and colleagues (Jiang et al., 2017), the authors investigated changes of T2 relaxation times in several brain regions as well as blood glucose levels in severely scalded rats. They concluded that quantitative T2 mapping is a sensitive method in detecting and monitoring scald injury of rat brain. Among the several brain regions evaluated in the study, hippocampus showed an apparent pattern with time elapsing in terms of changes of T2 relaxation times. The study demonstrated a quantitative imaging tool to investigate the effect of stress injury on brain regions and its progression. In the article written by Li Y and colleagues (Li et al., 2017), non-ionic (gadolinium diethylenetriamine-pentaacetic acid bismethylamide, Gd-DTPA-BMA) and ionic (gadopentetate dimeglumine, Gd-DTPA) gadolinium-based contrast agents were evaluated for the quantitative assessment of C6 glioma with dynamic contrast-en hanced MR imaging (DCE-MRI). The results showed that Gd-DTPA-BMA had significantly more pixel counts of glioma in a capillary permeability map, known as k^{trans} map, and increased tendency in the average k^{trans} values, indicating that DCE-MRI with Gd-DTPA-BMA can be more suitable for the evaluation of glioma. Even though functional MR imaging has already contributed significantly to several aspects of personalized medicine, including diagnosis, treatment planning, response assessment, and prognosis, standardization of these imaging techniques is urgently needed, and should become the focus of future studies (Benz et al., 2016).

Today radiology is facing challenges to considerably improve its value by delivering higher quality and better outcome with a lower cost (Dunnick et al., 2015). Towards this end, robust MR imaging methods are pivotal to obtain and interpret the imaging results timely and accurately. Efforts are required to accelerate translation from bench to bedside by implementing the advanced techniques into patient care protocols. The ultimate value of an emerging MR imaging technique resides in not only its technical novelty, but also how well it can benefit clinical practice. New imaging techniques should be thoroughly evaluated in terms of accuracy, reliability, safety, and cost-effectiveness as compared with current clinical practice. More importantly, interpretation of the MR imaging results must be demonstrated in the context of addressing a clinical question that is relevant to the outcome through improved management of the individual patient. Yang D and colleagues (Yang et al., 2017) evaluated and compared the diagnostic accuracy of apparent diffusion coefficient (ADC) values for the characterization of solid focal liver lesions (FLLs). The mean ADC values and lesion-to-liver ADC ratios were compared between benign and malignant solid FLLs. Receiver operating characteristic analysis was performed to evaluate the diagnostic accuracy of ADC values and ADC ratios in discriminating benign from malignant solid FLLs. The results demonstrated that the mean ADC value, as well as the mean ADC ratio of benign solid FLLs, was significantly higher than that of malignant lesions. The results have provided new insights into differentiation of focal liver lesions to improve the current clinical practice. In the article written by Li F and Wang X (Li and Wang, 2017), the correlation between carotid plaque features and the Framingham risk category was assessed among 160 asymptomatic subjects. The carotid plaque was evaluated by using multi-contrast MR which takes advantage of the great versatility of MR imaging. This study demonstrated that a substantial proportion of advanced carotid plaques can exist even in the low or intermediate-risk individuals evaluated using the conventional Framingham risk score (FRS). This study is significant as it can potentially detect subclinical vascular disease in individuals who are usually asymptomatic. If these individuals were left untreated, they could develop both physical and cognitive dysfunctions. The authors concluded that multi-contrast MR imaging may provide valuable and complementary information to FRS for identifying asymptomatic at-risk individuals who can benefit from targeted preventative therapy.

The dramatic changes occurring in the health care environment bring radiologists both challenges and opportunities (Mendelson et al., 2013). One of the most promising opportunities is the information technology (IT) for personalized medicine. With the help of IT tools, radiologists can deliver the service more efficiently and accurately while improving the quality. Integration of IT solutions into daily radiology practice is also expected to lead to new ways for the delivery of radiologic services enabled by emerging MR imaging technologies. In the article written by Su Q and colleagues (Su et al., 2017), the authors introduced a new medical imaging processing method based on a human cognitive model. As MR imaging continues to evolve, analysis of a large amount of MRI data for each patient becomes an important barrier that prevents radiologists from delivering quality patient care with high efficiency. For example, a vast amount of dynamic MRI images over a time course, such as in the case of a DCE-MRI scan, represents a major bottleneck for timely transmitting the images through internet or PACS for remote reading and analyzing. The results showed that a prioritization method could automatically assimilate and determine the content of the DCE images. They have demonstrated a high degree of consistency between radiologists' findings and those from a prioritization algorithm using the proposed method. The authors concluded that this method produced reliable results by employing liver MR images as an example, which paved the way for expanding the method to studying other organs. In another study by Gao G and colleagues (Gao et al., 2017) to improve diagnostic efficiency, 13 quantitative image features were automatically extracted from diffusion-weighted images of the prostate using computer-aided diagnosis (CAD) enabled by an artificial neural network (ANN) algorithm. The importance of each feature in cancer identification was compared in the peripheral zone and transition zone, respectively. The results showed that most of the features were significantly different between prostate cancer (PCa) and non-PCa in the peripheral zone. The authors concluded that CAD could predict the existence of PCa, with a high accuracy and specificity while maintaining an acceptable sensitivity. More importantly, the results indicated that the outcome predicted by the CAD approach correlated strongly with the scores graded by experienced radiologists according to the prostate imaging and reporting data system (PI-RADS v2) (Purysko, et al., 2016). In addition to improving diagnosis, radiology informatics can also be used to enhance workflow, conduct quality controls, integrate clinical and research data, and enable data mining under the concept of Big Data. The IT innovations bring new concepts to keep radiology professionalism at the forefront of technologies that aim at increased values (Mendelson et al., 2013).

For more than four decades, MR imaging has contributed immensely to modernizing medicine. There is compelling evidence that MR imaging will contribute even more to personalized medicine in the decades to come. This collection of six research papers is not intended to provide a thorough coverage of this exciting and expanding field of MR imaging. Instead, through these six specific examples, it is our hope that the readers can appreciate the extensive breadth and incredible depth of ongoing research in MR imaging for personalized medicine, spanning from basic sciences, clinical translation, outcome studies to informatics, with abundant opportunities to shape our future practice of radiology (Yu et al., 2015).

Compliance and ethics *The author(s) declare that they have no conflict of interest.*

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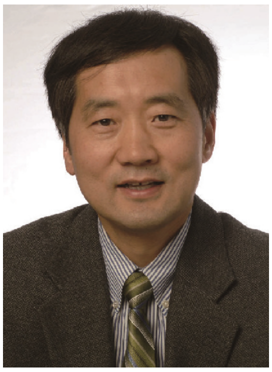
Biographical Sketch

Xiaoying Wang, M.D., is a Professor in Radiology Department, Peking University First Hospital. She obtained her doctor's degree from Beijing Medical University, in 1999, with the degree thesis focusing on MR imaging. Then she was recruited to Peking University First Hospital as a radiologist and worked on clinical, educational and research work, particularly on the development of new imaging techniques and the clinical application. In 2006, Dr. Wang started to work at Academy for Advanced Interdisciplinary Studies (AAIS) in PKU, and continued her research on medical informatics. In the past years, she has made contributions on the multiparametric prostate MRI and functional renal MRI.



Xiaohong Joe Zhou, Ph.D., is a tenured Professor of Radiology, Neurosurgery, and Bioengineering at the University of Illinois at Chicago (UIC), USA. He also serves as Director of 3T MRI of UIC's Center for MR Research and Chief Medical Physicist for the UIC Hospital. Dr. Zhou is a graduate of Peking University (Beijing, China) where he obtained a BS degree in Physical Chemistry. He entered the field of MRI in 1987 and earned his Ph.D. degree in 1992 from University of Illinois at Urbana-Champaign. After postdoctoral training at Duke University Medical Center, Dr. Zhou worked as a senior physicist at General Electric Medical System and was on the faculty of The University of Texas M.D. Anderson Cancer Center prior to relocating to UIC in 2003. Dr. Zhou's research focuses on novel MRI pulse sequences, diffusion imaging, and their applications to cancer. He is a Fellow of the International Society for Magnetic Resonance in Medicine (ISMRM), and a member of Board of Directors, The American Board of Medical Physics (ABMP).