[SY09] Advanced MRI Symposium

SY09-01

Parotid MRI as a model for cross-disciplinary research

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The parotid glands are the largest of the three salivary glands in humans. Developments of noninvasive MR imaging approaches for tissue characterization of the parotid glands have not received wide attention, likely due to cost-benefit concerns facing easy clinical access with conventional biopsy procedure. Nonetheless, several technical challenges such as fat contamination, air-tissue interface, and/or presence of metallic dental implants, render MR imaging of the parotid glands an ideal model for dedicated cross-disciplinary research. The property of reduced competition due to relatively minor clinical significance is particularly suited for research laboratories that are not as resourceful as those internationally top-leading teams. For the past decade, we have successfully attempted functional parotid MR imaging with reduced geometric distortions using multi-shot diffusion-weighted MR imaging, parotid perfusion MR imaging using dynamic contrast-enhancement with effects of fat contamination investigated, and quantification of parotid fat contents via iterative fat-water separation methods in the presence of dental implants. With these tools, the parotid fat content baseline has been established for the healthy population for both genders at wide age ranges. Accuracy has been assessed by comparing three MR imaging quantification methods. Age dependency of the apparent diffusion coefficient has also been thoroughly examined. After healthy subject investigations, the MR imaging methods have been applied to longitudinal characterization of radiation injury to the parotid glands following spared radiotherapy of head-and-neck cancer, as well as to noninvasive differentiation of Warthin tumor from pleomorphic adenomas and carcinomas. Other recent advances include the imaging exploration of instantaneous changes in the parotid characteristics following gustatory stimulations, and the applications of the parotid MR imaging experience to other organs such as the liver. We believe that through these years of efforts, investigators who joined these projects are now equipped with the essential expertise for further advancements of other clinically unmet needs related to MR imaging.

Keywords : Parotid glands, Diffusion imaging, Fat quantification, Age dependency, Gustatory stimulations

[SY09] Advanced MRI Symposium

SY09-02

Distortion-free Echo Planar Imaging

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Echo planar imaging (EPI) is one of the most efficient MRI acquisition techniques. It has been widely used for either diffusion weighted MRI (DWI) or dynamic imaging in the clinical. The main challenge for EPI is the B0 field inhomogeneity induced distortion, T2* relaxation induced blurring artifacts and low image resolution. Multishot based techniques such as interleaved EPI or readout segmented EPI can mitigate these problems, but they can only suppress image distortion instead of removing distortion completely. So high fidelity EPI based acquisitions are still desirable for precise diagnosis and surgery planning. Point spread function (PSF) encoded EPI has been proposed to achieve high resolution, distortion- and T2* blurring- free imaging in 1997 by Robson (Robson, MRM, 1997). But it took an extremely long acquisition time, thus is not practical for most applications. Traditional parallel imaging such as SENSE and GRAPPA can be used for PSF-EPI, however the acquisition efficiency is very low, especially for multiple direction diffusion encoding. In this presentation, we will introduce a method, termed “tilted-CAIPI”, to make PSF-EPI more practical by using significantly high acceleration. The performance is validated by phantom and in vivo studies for anatomical imaging and diffusion imaging. In addition, PSF-EPI can also provide quantitative information, such as T2* values. This technique can be used for fat-water separation and fat quantification, which can be useful for fat suppression when traditional fat suppression methods fail. Other features about this technique will also be presented.

Keywords : Echo-planar imaging; point spread function mapping; distortion correction; diffusion imaging; parallel imaging

[SY09] Advanced MRI Symposium

SY09-03

Cerebral Blood Flow Changes in Patients with Chronic Kidney Disease

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Chronic kidney disease (CKD) is associated with alterations in blood pressure (BP), blood chemistry, and red blood cell production that can potentially affect brain function. Previous studies in adults have shown that CKD is associated with subcortical ischemic lesions, atrophy, and deficits in cognitive performance. Given the high incidence of cardiovascular disease in CKD and the associations between CKD and neurological dysfunction, further characterization of cerebrovascular function in CKD is highly relevant. While CKD in adults is often a consequence of age-related disorders such as hypertension and diabetes, childhood CKD often occurs congenitally, yet still affects brain development and cognitive function. Examining cerebrovascular function in a pediatric population with CKD provides the potential to dissociate CKD effects from those of associated chronic hypertensive vasculopathy. Arterial spin labeled (ASL) magnetic resonance imaging (MRI) provides noninvasive CBF quantification without exogenous contrast. Reduced hematocrit (Hct), as commonly occurs in CKD, can prolong the T1 of arterial blood, which is a key parameter in ASL CBF quantification. We observed significant differences in blood T1 depending on the approach used, leading to different findings for both sex and group differences in CBF. Our findings highlight the importance of blood T1 in ASL CBF quantification, especially for patients such as CKD, with significant change of Hct. Hct-corrected blood T1 minimized spurious correlations of CBF with Hct while preserving expected correlations. Patients with CKD showed higher global CBF compared with controls that was attributable to reduced hematocrit. A correlation between white matter CBF and blood pressure was observed in patients, suggesting altered cerebrovascular autoregulation. Regional CBF differences between patients and controls included regions in the “default-mode’ network. CKD subjects with positive extrema in the precuneus showed a strong correlation with executive function. Our results confirmed systemic effects of estimated glomerular filtration rate, Hct and BP on CBF and alterations in regional CBF may reflect impaired brain function underlying neurocognitive symptomatology in CKD. These findings further characterize the nature of alterations in brain physiology for children, adolescents, and young adults with CKD, who do not have pre-existing cardiovascular disease.

Keywords : Arterial spin labeled MRI, Chronic kidney disease

[SY09] Advanced MRI Symposium

SY09-04

High resolution 3D MR Fingerprinting

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Since the first publication of magnetic resonance fingerprinting (MRF) in 2012 Nature for the fast quantitative PD, T_1, T_2 mapping, various technical and clinical MRF researches were reported. These MRF researches were developed and validated with different scanners (Siemens, GE and Phillips), using many phantoms and for various applications such as brain, cardiac, abdomen, breast, prostate and etc. Despite these promising results, most of the studies were based on 2D acquisition with the millimeter range resolution, in the range of (1~2)x(1~2) mm^2 for in-plane and (3~5) mm for slice thickness, and the scan times were around (8~15) s/slice.

For the 3D MRF acquisitions, several challenges were presented, 1) long acquisition time due to the increased the number of excitations to fill the k_z partition data, 2) long reconstruction time due to the huge data size, 3) B_1 inhomogeneity issues and etc. Furthermore, SNR was also problematic when the iso (1mm^3) or sub-millimeter (<1mm^3) resolution 3D MRF data were acquired.

Recently, a few 3D MRF studies were published. In 2016, the first 3D MRF with the music sound was reported by Dan Ma et al. It takes 18.4 min with 1.2x1.2x3mm^3 resolution and FOV 300x300x48mm^3 which is not practical even if the music sound was fascinating. In 2017, two 3D MRF researches were published. Dan Ma et al. presented a 3D MRF for a whole-brain coverage with 1.2x1.2x3mm^3 resolution (FOV 300x300x144mm^3) in 4.6 min scan time. To reduce the scan time, undersampling through the k_z axis, similar with k-t acceleration method, was applied to stack-of-spiral 3D MRF scheme. The other method which was applied with sliding window and 3D GRAPPA reconstruction to the stack-of-spiral 3D MRF acquisition was suggested by Congyu Liao et al. They showed 1mm^3 iso resolution full brain PD, T1, T2 mapping in 7.5 min acquisition time.

For the clinical application of the 3D MRF, two papers were published. In 2018, 0.6mm^3 (interpolated from 1.2mm^3, scan time : 12min) full brain 3D MRF was proposed by Dan Ma et al for detection and characterization of epileptic lesions. To overcome SNR issue due to the high resolution voxel size, Kt-SVD reconstruction method was applied. The other published 3D MRF application is breast cancer imaging suggested by Yong Chen et al. in 2019. 3D breast PD, T1, T2 map were acquired with 1.6x1.6x3mm^3 voxel size (FOV 400x400x144mm^3) in 6min. Higher T2 relaxation time was observed in invasive ductal carcinoma.

A 3D MRF technique with very high resolution (0.5x0.5x1mm^3) for the MSK imaging was also developed by our group. It only takes 7 min 10 sec to acquire high resolution 3D PD, T1, T2 map for a whole cartilage coverage in knee (FOV 160x160x120mm^3). To overcome the concerns of the 3D MRF, a hybrid radial-cartesian with multi-shot EPI MRF pulse sequence was developed and SVD+CG-SENSE for the reconstruction was applied. Higher T2 relaxation time in cartilage was observed in patellofemoral chondromalacia patient.

In conclusion, we summarized 3D MRF techniques and applications. Furthermore, sub-milimeter resolution 3D MRF was proposed.

Keywords : Fast imaging, Quantitative imaging, 3D MRF