High resolution DCE MRI of the Pituitary gland using Radial K space Aquisition with Compressed Sensing Reconstruction

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Introduction: The pituitary gland is a pea-sized endocrine gland located outside of the blood-brain barrier at the bottom of the hypothalamus. Pathologies of the pituitary gland include benign micro- and macroadenomas (most common), invasive adenomas, or carcinomas (least common). Benign adenomas represent 10% to 25% of all intracranial neoplasms, with an estimated prevalence rate of 17% in the general population. MRI is the current gold standard to evaluate these pathologies and is conventionally performed in a dynamic manner using slice-selective T1w TSE sequences before and at multiple time points after the injection of a gadolinium-based contrast agent, with a usual duration of ~ 32 sec / scan. This allows for assessment of regions within the gland with differential enhancement and, thus, underlying pathology. However, due to the typical slice thickness of 3 mm, identification of small tumors can be difficult, in particular for microadenomas which by definition have a diameter of less than 10 mm and thus are often covered by only 1 or 2 slices.

Recently, we developed a novel approach for dynamic T1w MRI called GRASP, based on a radial "stack-of-stars" 3D GRE sequence (Radial VIBE) with golden-angle ordering scheme[1]. Compared to conventional 2D TSE exams, it provides significantly higher through-plane resolution, improved robustness to motion and flow[2], and fat suppression. Dynamic imaging is possible by acquiring data continuously while the contrast agent is injected, instead of performing multiple separate exams. Image reconstruction is then achieved by binning the data into sequential time frames and reconstructing the frames with an iterative method that combines parallel imaging and compressed sensing[3]. By employing a total-variation constraint along time, GRASP is able to reconstruct images from highly undersampled data, offering simultaneous high spatial and temporal resolution. As a unique feature, the desired temporal resolution can be selected retrospectively and can be chosen as high as ~ 2.5 sec / frame.

The purpose of this work is to demonstrate the application of GRASP for dynamic pituitary-gland imaging in routine patients. As a first validation study, signal-time curves of normal-appearing pituitary glands were analyzed for enhancement differences in the anterior, posterior gland and median eminence.

Methods: A retrospective HIPAA compliant study was then performed in 79 patients with normal appearing pituitary gland (M:F=20:59). Imaging was performed in coronal orientation at 1.5 T (Siemens MAGNETOM Avanto) and at 3 T (Siemens MAGNETOM Trio / Skyra) using two protocol variants. Exams at 1.5 T were performed using 0.8 mm isotropic resolution, 44 slices, 180 mm FOV, FA 12°, BW 180 Hz/pixel, TE/TR=3.9/10.5 ms, 224 pixel base resolution, 600 spokes, and 188 sec acquisition time. Exams at 3T used 0.7 mm in-plane resolution and 1 mm slice thickness, 32 slices, 180 mm FOV, FA 9.5°, BW 391 Hz/pixel, TE/TR=2.4/6.4 ms, 256 pixel base resolution, 944 spokes, and 164 sec acquisition time. For both protocols, 0.01mmol/kg of gadopentetate dimeglumine was injected 20 sec after the start of the scan. The acquired data was exported and reconstructed offline using a C++ implementation of the GRASP algorithm[4], creating 9 dynamic image frames with temporal resolution of 19.7 sec for 1.5 T, and 18.0 sec for 3 T. Reconstructed images were sent to the PACS archive and analyzed using the OLEA Sphere 2.2 software.

Regions of interest (ROI) were placed in the anterior gland, median eminence, and posterior pituitary gland. Sagittal reconstructions confirmed placement of ROIs within their respective locations. The ROIs were used to generate signal-time curves, which were subsequently analyzed for temporal enhancement differences within the gland. A statistical analysis with SAS 9.3 software (SAS Institute, Cary, N.C.) was performed using a paired-sample Wilcoxon (W) signed rank test to evaluate the mean peak values, mean time of maximum enhancement (TME), mean area under the curves (AUC), and mean wash-in and wash-out in the ROIs.

Results: Figure 1 shows the reference images obtained in the GRASP exams indicating the locations of the ROIs. Figure 2 shows corresponding signal-time curves. Evaluation of the curves from the anterior pituitary, median eminence, and posterior pituitary gland show different patterns of enhancement. The results from the statistical analysis are summarized in Table 1. Curves from the posterior pituitary gland and median eminence demonstrate a faster wash-in (9.14 and 8.54 respectively) and TME (58.96 and 62.60 seconds respectively) with a lower peak of enhancement compared to anterior pituitary gland, which instead show a slower wash-in (10.92) and delayed TME (86.55 seconds) with higher peak of enhancement (754.94). Compared to the posterior pituitary gland, anterior pituitary and median eminence show a faster washout (1.52 and 1.56 versus 1.90). These findings are consistent across patients with a mean significance level of $p<0.005$.

	ANTERIOR		NEURO		STALK	
MEASURE	MEAN	SD	MEAN	SD	MEAN	SD
AUC	699980.65	201669.32	375001.10	177011.73	402446.20	166526.70
PEAK	754.94	242.04	439.61	205.67	446.62	192.66
TME	86.55	19.23	58.96	16.23	62.60	18.70
WASHIN	10.92	3.89	9.14	4.20	8.54	3.71
WASHOUT	1.52	1.34	1.90	1.48	1.56	1.27

Table 1. For each parameter mean and standard deviation were calculated in anterior, posterior pituitary gland and median eminence.

Discussion: The pituitary gland has a unique blood supply deeply connected with its functionality; with the median eminence (the pituitary stalk), the anterior pituitary gland and the posterior pituitary gland having different vascularization patterns. At the level of the median eminence, the superior hypophyseal arteries anastamose with the inferior hypophyseal arteries to form the primary plexus. From this level, the portal veins arise and form a secondary plexus to supply the anterior pituitary gland. In contrast the posterior pituitary gland is supplied by the inferior hypophyseal arteries.

Our results show a higher maximum and mean enhancement in the anterior pituitary gland compared with the median eminence and the posterior pituitary gland. This finding is consistent with the underlying perfusion characteristics, with the anterior pituitary gland being the most richly vascularized tissue of the body. Moreover we found lower TME and faster wash-in in the median eminence and posterior pituitary gland compared to the anterior pituitary gland. This result may reflect the difference in the anatomic origin of the superior and the inferior hypophyseal arteries, which are branches ofthe internal carotid artery, with the former arising more distally than the latter[5]. Utilizing such signal-time curves obtained with the GRASP technique provides a hitherto unexplored quantitative estimation of perfusion characteristics of the normal and abnormal pituitary gland.

Conclusions: Dynamic imaging of the pituitary gland using GRASP is feasible in clinical practice and provides improved spatial and temporal resolution compared to conventional dynamic MRI protocols. In addition, due to the higher achievable imaging speed, it enables quantitative assessment of temporal variances in the signal enhancement patterns, as demonstrated here for the normal perfusion difference between the anterior,posterior pituitary gland and median eminence. This capability promises to facilitate precise identification and characterization of pituitary-gland disorders in routine exams.

References: 1. Winkelmann et al, IEEE TMI 2007; 26: 68–76 2. Chandarana H, et al. Invest Radiol 2013; 48:10-6 3. Feng L, et al. MRM 2013; early view 4. Block et al, ISMRM 2003: 3809 5. Tien R. AJR 1992; 158:651-654

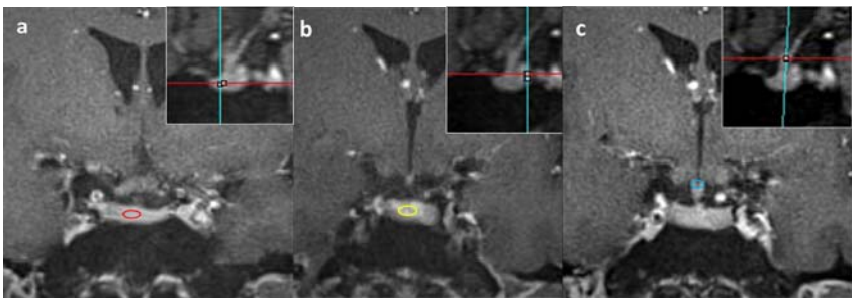

Fig.1: GRASP images from one patient showing the ROIs in the (a) anterior gland, (b) posterior gland, and (c) median eminence. Sagittal reference planes are shown top right.

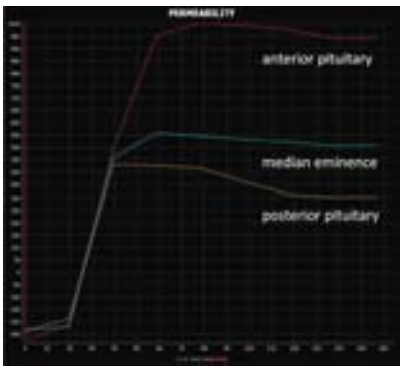

Fig. 2: Corresponding signal-time curves obtained from the ROIs shown in Fig. 1: anterior (red), posterior pituitary gland (yellow) and median eminence (light blue).