T1 CUBE compared to Fast Spin Echo T1 Weighted and BRAVO in post contrast enhanced brain MRI at 3T

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Purpose: During the last ten years, 3T MR scanners have become increasingly useful in medical imaging with their increased SNR capabilities and potential of higher resolution images. 3D volumetric brain imaging holds special promise for high SNR, spatial resolution and multi-plane reformat possibilities, particularly at 3T. However, with some existing pulse sequences, mediocre lesion contrast enhancement, image artifacts, excessive meningeal and pial vascular enhancement, and increased signal from white matter pose challenges to the assessment of small and subtle enhancing lesions at 3T. A T1-weighted fast spin echo-based 3D sequence could hold certain advantages over gradient echo-based sequences and 2D fast spin echo imaging [1]. The purpose of this study was to compare the quality of imaging and contrast enhancing lesion conspicuity of 3D volumetric fast spin echo-based (FSE) T1 CUBE with that of a T1 weighted 2D FSE and 3D volumetric T1-weighted IR prepared 3D GRE (BRAVO) in contrast enhanced 3T brain MRI.

Methods: The post-gadolinium brain scans in 15 clinical subjects were retrospectively reviewed. All imaging was performed on either a 3T Signa HDxt or a MR750 MR scanner (GE Healthcare, Waukesha, WI) using an eight-channel head coil. In all patients, at least two of the three post-gadolinium T1-weighted pulse sequences (T1 CUBE, 2D FSE, BRAVO) were performed, and all three were performed in 13/15. T1 CUBE is based on a 3D FSE pulse sequence which employs modulated refocusing flip angles, an auto-calibrating hybrid space parallel imaging scheme and an optimized view-ordering scheme for a non-separable k_y-k_z grid [2]. Scan parameters for T1 CUBE were as follows: TR/TE 600 ms/11.5 ms, $\pm$83.3 kHz bandwidth, 1 mm section thickness, number of sections 200, 256x256 matrix, echo train length 24, 0.5 NEX, 24 cm FOV, scan time 4:39 min. Scan parameters for BRAVO were as follows: TR/TE/TI 7.8 ms/3 ms/450ms, $\pm$32 kHz bandwidth, 1.2 mm section thickness, number of sections 200, 256x256 matrix, flip angle 12, 1 NEX, 24x21 cm FOV, scan time 4:20 min. Scan parameters for the coronal FSE T1 weighted scan were as follows: TR/TE 800 ms/14 ms, $\pm$21 kHz bandwidth, 4-5 mm slice thickness, number of slices 30, 256x256 matrix, flip angle 12, 1 NEX, 16-18 cm FOV, scan time 4:00 min.

Coronal reformatted (2.3mm partition, 1.0mm overlap for T1 CUBE; 2.8mm partition, 1.0mm overlap for BRAVO) or primarily acquired images (4-5mm sections, no overlap for 2D FSE T1) were reviewed with consensus by two CAQ-certified neuroradiologists. The following parameters were qualitatively assessed on scales of 1-5: SNR, CNR for grey-white differentiation, CNR for contrast-enhancing (CE) lesions if present, degree of enhancement of meninges and pial vessels, and overall image quality for contrast-enhanced T1-weighted imaging. Radiologists' order of preference among the three imaging sequences was also assessed.

Results: Median scores for CNR between grey/white matter, CNR for contrast-enhancing lesions, contrast enhancement (CE) of the meninges and the pial vessels, overall image quality and preferred sequence are listed in Table 1. BRAVO had highest contrast between grey/white matter and greatest degree of contrast enhancement in the meninges and the pial vessels. However, the CNR for contrast-enhancing lesions and overall image quality were deemed highest with T1 CUBE, and T1 CUBE was the preferred sequence in 10/15 cases. 6/15 subjects had enhancing primary brain tumors, 3/15 had venous angiomas, 2/15 had facial tumors, and 4/15 had no enhancing abnormalities. The general consensus was that the greatest artifacts related to pulsatility were seen with 2D FSE T1-weighted imaging.

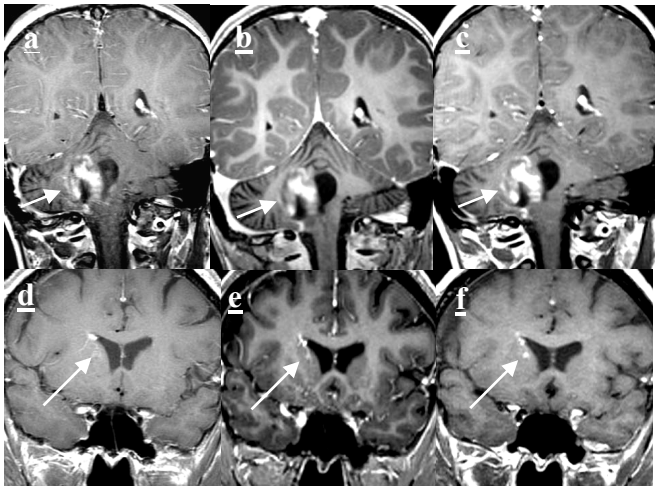

Fig. 1: a, d: 2D FSE T1-weighted; b, e: BRAVO; c, f: T1 CUBE. **TOP ROW**: The 2D FSE T1W and T1 CUBE images give superior depiction of the margins of this enhancing cerebellar tumor, in part because of greater CNR of contrast-enhancing tumor to adjacent cerebellar white matter. **BOTTOM ROW**: A channel of this venous angioma is best appreciated with the T1 CUBE, because of greater CNR relative to BRAVO and probably because of smaller section thickness relative to 2D FSE T1W.

	FSE T1	BRAVO	T1 CUBE
CNR Grey/White matter	3	5*	3
CNR Lesion	4	3*	5
CE- Meninges/Pial	3*	4*	2
Overall IQ	3	3	4
Preferred Sequence	4/15	1/15	10/15

Table 1: Median scores. *Denotes statistical significance ($p<0.05$) in a pair-wise comparison with T1 CUBE using the Wilcoxon Signed-Rank Test.

Discussion: Preliminary results are promising using T1 CUBE for post contrast enhanced T1 weighted brain exams at 3T. T1 CUBE has a flat image contrast that is preferred when looking for subtle or small enhancing lesions during a 3T exam, whereas the relatively higher signal intensity of white matter in BRAVO images decreases CNR of contrast-enhancing lesions in the white matter. Also, meningeal or juxtameningeal enhancing lesions could be better appreciated on images with less meningeal and pial vascular enhancement, such as T1 CUBE and 2D FSE T1-weighted imaging, though this patient sample did not provide enough meningeal enhancing lesions for this evaluation. The thin section reformats available with T1 CUBE and diminished artifacts from vascular pulsatility in the posterior fossa are advantages of T1 CUBE over 2D FSE T1-weighted imaging. T1 CUBE holds promise as a 3D volumetric T1-weighted pulse sequence that is sensitive to contrast-enhancing lesions, and its performance will continue to be tested in larger groups of patients.

References: [1] Kato et al. AJNR, 30:923–29 (2009) [2] Busse et al. MRM, 60:640-649 (2008)