A radial 3D GRE-EPI pulse sequence with k_z blip encoding for whole-brain isotropic 3D perfusion using DSC-MRI bolus tracking with sliding window reconstruction (3D RAZIR)

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INTRODUCTION: Bolus tracking with DSC-MRI demands rapidly acquired T_2^*-weighted MR images for measuring cerebral perfusion. Current implementations of DSC-MRI are constrained by a temporal resolution of approximately 2 s to adequately characterize the bolus,[1] with tradeoffs in SNR, spatial resolution, and volume coverage. We introduce 3D RAZIR, a new 3D GRE-EPI pulse sequence that obtains 76-slice whole-brain relative perfusion measurements with DSC-MRI bolus tracking at 1.7 × 1.7 × 1.7 mm^3 isotropic voxel resolution.

METHODS: *Sequence design*: 3D RAZIR uses in-plane radial sampling and through-plane Cartesian sampling to produce a cylindrical 3D *k*-space (Fig. 1). Consecutive 3D volumes are acquired in 10.3 s for bolus tracking. The use of a large temporal resolution is known to distort the bolus profile,[1] but dynamic bolus information is recovered at 160 ms per frame prior to perfusion analysis using sliding window reconstruction.[2]
Subjects: One patient with angiographically-confirmed Moyamoya disease was recruited with IRB approval.
Image acquisition: In vivo bolus tracking was performed using 3D RAZIR and a typical 2D GRE-EPI pulse sequence[3] (voxel size 1.7 × 1.7 × 5.0 mm^3) as a reference standard with a 3.0 T MR scanner (Tim Trio, Siemens AG, Erlangen, Germany). 3D RAZIR scan parameters: second injection, TE/TR = 36/81 ms, flip angle = 45°, slices = 76, voxel size = 1.7 × 1.7 × 1.7 mm^3, repetitions = 12. Images were acquired with a single-dose injection of 0.1 mmol/kg Gd-DTPA at 4 mL/s. Inline phase correction scans were used in 3D RAZIR to correct radial view-dependent N/2 ghosting artifacts.
Data analysis: Sliding window reconstruction was used to increase the reconstructed frame rate of 3D RAZIR from 10.3 s to 0.16 s per measurement using a sliding window factor of 64 before perfusion analysis. Both acquisitions were processed using a standalone program[3] in Matlab to produce parametric maps of relative cerebral blood flow (rCBF), relative cerebral blood volume (rCBV), and mean transit time (MTT).

RESULTS AND CONCLUSIONS: Figure 2 compares coronal, sagittal, and axial perfusion maps in 3D RAZIR (left) and the 2D GRE-EPI reference (right). Increased coverage in 3D RAZIR allows for fine resolution of the perfusion metrics in the through-plane direction while the reference is blurred. Using an ROI analysis, we obtained gray/white matter CBF ratios of 2.38 in the reference and 2.18 in 3D RAZIR, in close agreement with literature values.[4] CBF maps were coregistered prior to comparison (SPM, Wellcome Department of Cognitive Neurology, London, UK). Despite using a temporal resolution of 10.3 s, 3D RAZIR is able to obtain whole-brain perfusion measurements with good reference standard agreement. Sliding window reconstruction permits the use of an extended temporal acquisition window without sacrificing SNR for bolus tracking. 3D RAZIR would be desirable for whole-brain study of neurovascular pathologies like stroke, cerebrovascular occlusive disease, and Alzheimer's.

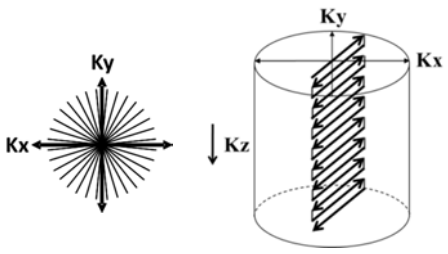

FIG 1. In-plane radial (left) and through-plane Cartesian sampling (right) is used to produce a cylindrical 3D *k*-space. Each TR acquires a single radial view in-plane during which all k_z partitions are sampled using a 3D GRE-EPI readout.

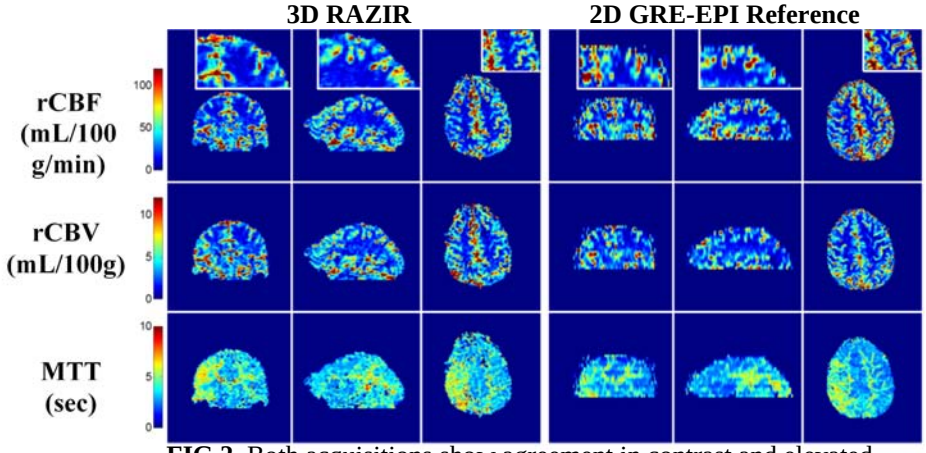

FIG 2. Both acquisitions show agreement in contrast and elevated MTT consistent with Moyamoya disease. 3D RAZIR more clearly illustrates the pathology with isotropic voxels.

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