An Optimized 3D Inversion Recovery Prepared Fast Spoiled Gradient Recalled Sequence for Carotid Plaque Imaging

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Introduction

Intraplaque hemorrhage into the carotid atherosclerotic plaque has been shown to create instability and progression. Moody et al developed a T_1-weighted magnetization-prepared 3D gradient echo sequence to characterize the hemorrhagic carotid plaque at 1.5T with a good level of success (1). We have developed an optimized 3D inversion recovery prepared fast spoiled gradient recalled sequence (IR FSPGR) on a GE 3T EXCITE scanner for carotid plaque imaging. It can potentially be used to replace the more traditional quadruple inversion-recovery (QIR) T_1-weighted 2D black-blood carotid imaging technique (2) in the detection of plaque hemorrhage and offer additional benefits of high-resolution volumetric visualization with multi-planar reconstructions.

Methods

This sequence (Figure 1) was developed by modifying the existing 3D IR FSPGR on a GE 3T EXCITE scanner. The modifications include a 180° non-selective inversion recovery (IR) preparation RF pulse, an inclusion of fat signal saturation pulses on every encoding step and a sequential phase encoding in the slice direction. The 180° non-selective inversion RF pulse inverts spins within the entire sensitive volume of the RF transmitting coil. By properly selecting the time of inversion (TI) based on the T_1 of the blood, the signal from the blood flow can be minimized to reach the maximum contrast between the carotid vessel lumen and the vessel wall. Fat saturation is applied on every data acquisition step to allow sufficient suppression of the fat signal. This is especially important when a surface coil is used. Selecting a sequential phase encoding in the slice direction has provided good scan time efficiency. Since TI is equal to the time from the non-selective RF pulse to the middle of the phase encoding steps in the slice direction, by properly selecting the number of slice phase encoding steps, the "dead" time TIprep (the time from the non-selective RF pulse to the beginning of the first encoding step) can be minimized.

The protocol with a total scan time of 4 minutes and 20 seconds has been used for collecting our preliminary data with a dedicated 4-channel or 6-channel carotid surface coil: TE (time of echo) = 3.2 ms, the TR (time of repetition) for each phase encoding step = 13.2 ms, the TR with respect to the non-selective inversion = 674 ms, TIprep = 40 ms, TI = 357 ms, flip angle = 15°, receiver bandwidth = ± 31.25 kHz, field of view = 15 cm, number of slices = 48, slice thickness = 1 mm, matrix size = 256 x 192, and number of excitation = 2.

Results and Discussion

Images (Figure 2) from the optimized 3D IR FSPGR technique show clear blood and fat signal suppression at the carotid region. This allows clear visualization of blood lumen. A hyper-intense hemorrhagic region was also found with the optimized 3D IR FSPGR technique, and the hemorrhage was confirmed later with histology. In this case, the boundaries of the hemorrhagic region on QIR T_1-weighted and the 3D time-of-flight (TOF) images were less distinct. Detailed comparison on 3D IR FSPGR with QIR T_1-weighted and 3D TOF MRA using histological validation is ongoing. The double inversion-recovery (DIR) T_2-weighted image (3) confirms that this is an acute hemorrhage with a short T_2 as seen at histology. However, a single-echo 3D IR FSPGR sequence cannot differentiate acute from recent hemorrhage. A dual-echo 3D IR FSPGR sequence that will be developed may be able to achieve high sensitivity and specificity for plaque hemorrhage detection and at the same time characterize the age of the hemorrhage. We are continuing to evaluate the benefits of this optimized 3D IR FSPGR technique for carotid plaque imaging.

References

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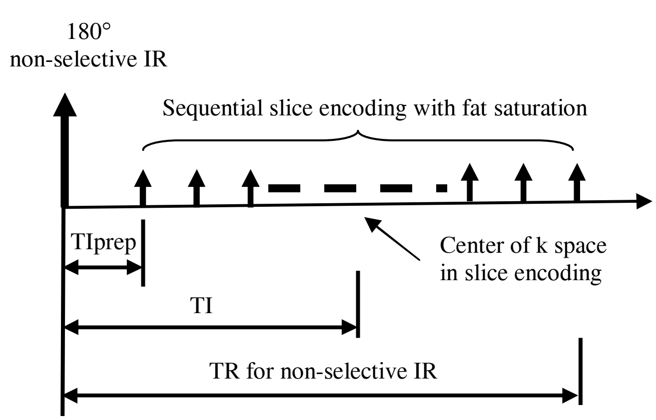

Figure 1. The timing diagram of the optimized 3D IR FSPGR sequence is shown.

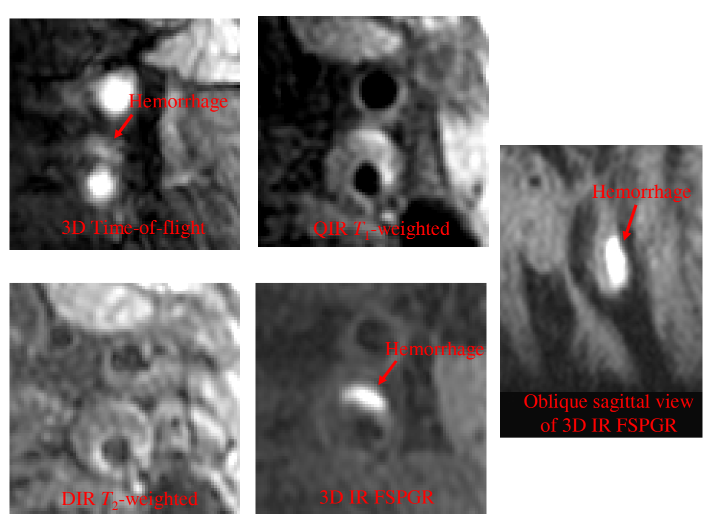

Figure 2. Images from different data acquisition techniques are compared, and the hemorrhagic region is indicated.