"Quiet-Zero TE" ASL brain MR angiography Can Outperform 3D TOF at 1.5T

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Purpose

Background:

Acoustic noise generated during magnetic resonance (MR) imaging is an unwanted side effect that may cause discomfort in patients and healthcare professionals. The problems associated with acoustic noise include simple annoyance, heightened anxiety, verbal communication difficulties (1), temporary hearing loss and, in extreme cases, the potential permanent hearing impairment (2-4). Temporary shifts in hearing thresholds have been reported in 43% of the patients scanned without ear protection and patients with improperly fitted earplugs (2). Additionally, acoustic noise may pose a particular hazard to specific patient groups who may be at increased risk (e.g., patients with psychiatric disorders, elderly, pediatric and sedated patients, newly born children) (4). Furthermore, noise exposure for the fetus could be of concern for both patients and interventional MRI staff (5).

The gradient magnetic field is the primary source of acoustic noise in MR procedures (4, 6). This noise occurs during the rapid alterations of currents within the gradient coils. These currents, in the presence of the strong static magnetic field of the MR system, produce significant (Lorentz) forces that act upon the gradient coils. Acoustic noise is produced when the forces cause motion or vibration of the gradient coils as they impact against their mountings, which, in turn, flex and vibrate (7, 8). The acoustic noise varies due to the alteration of the gradient output (rise time or amplitude) by modifying MR imaging parameters. Noise tends to be enhanced by decreases in section thickness, field of view, repetition time, echo time, and as field strength arises.

Gradient magnetic field-induced noise levels have been measured during a variety of pulse sequences for MR systems with static magnetic field strengths reporting sound pressure levels that can run as high as 100-120 dB. (6, 9-11). The situation is exacerbated in ultra-high speed imaging because of the very high switching rates used in these techniques. Noise levels can be as high as 140 dB, which is well above generally accepted safety level permitted in the workplace (7).

Hearing protection is applied routinely to all children and adults undergoing MR imaging. Earplugs, when properly used, can abate noise by 10 to 30 dB, which is usually an adequate amount of sound attenuation for the MR environment. Unfortunately, passive noise control methods suffer from a number of limitations. They affect the verbal communication with patients during the operation of the MR system, standard earplugs are often too large for the ear canal of adolescents and infants, and passive noise control devices offer non-uniform noise attenuation over the hearing range. While high
frequencies may be well attenuated, attenuation is poor at low frequencies. This is problematic because, for certain pulse sequences, the low frequency range is where the peak MR imaging-related acoustic noise is generated.

Several investigators have described the development of "quiet" pulse sequences, which substantially decrease acoustic noise and are acceptable for MR imaging and functional MRI examinations. To date two methods have been used to reduce noise - dampen/isolate the gradient coil from the patient bore, or reduce switching rate. Both methods have drawbacks; the first resulting in reduction of bore space and the second reducing performance. Quieter techniques are feasible which minimize gradient switching over the TR period by utilizing a 3D projection reconstruction with no excitation, pre-winding, phase-encoding, refocus, or crusher gradients. This technique can reduce acoustic noise levels by more than 30dBA while generating an isotropic volumetric acquisition. In addition, the nearly zero-TE nature of the "Silent" protocol has the potential to provide superior rendering due to reduced dephasing related signal loss.

"Quiet" ASL MRA is a new technique aimed for central cerebral artery imaging by combining ASL with 3D radial acquisition together. The ASL technique is optimized to create a constant labeling state with derated gradient switching, in order to reduce the acoustic noise. The 3D acquisition uses a spiral radial sampling scheme. It does not have an in-plane phase and frequency direction, as well as not having a slice selection phase. Due to the K Space trajectory and data sampling scheme, the gradient steps are relatively small, this accounts for the quiet behavior of this acquisition. Furthermore, the 3D acquisition acquires isotropic voxels and may be reformatted at the native resolution for no loss of spatial acuity. The acoustic noise is mainly created from the labeling component for "Quiet" ASL MRA.

The purpose of this study is to compare the quality of "Quiet" arterial spin labeling based (ASL-MRA) acquisitions to clinical 3D TOF techniques in current day to day practice for MRA imaging of the brain.

Methods and Materials

This is an on-going trial prospective study. Our aim is to include 20 subjects in this project and include two readers for the assessment of the images. Subjects will be scanned with the "Quiet" ASL MRA technique in addition to 3D-TOF on a 1.5T MR.

To date, 14 subjects have been included. 1 healthy volunteer (one women, 30 years old) and 13 patients (seven women, six men, age range 85-25) diagnosed with headache (n=2), toxoplasmosis (n=1), viral meningitis (n=1), sarcoidosis (n=1), AIT (n=1), stroke
(n=4), myoclonus (n=1) and seizures (n=1) were imaged after obtaining Institutional Review Board approval and informed consent. All exams were performed on a clinical 1.5 T magnetic resonance system (Optima 450W; GE Healthcare, Waukesha, WI) with an 8-channel head coil. Subjects were imaged with a clinical standard 3D TOF scan and a whole brain "Quiet" ASL MRA scan.

The standard 3D TOF scan was acquired with the following parameters: TR/TE 15/3.2 flow compensated; field of view 18 x 18 cm; matrix 384 x 224; slice thickness 1 mm; flip angle 20º; bandwidth 31.25 kHz; number of slabs 4 with an 8 partition overlap; slice thickness 1 mm/0.5 mm. The examination time was 3:59 min.

For the "Quiet" ASL MRA scan, the labeling plane was approximately placed at C1 segment of the internal carotid arteries such that the major feeding arteries of the brain vasculature including internal carotid arteries, external carotid arteries, and vertebral arteries will be labeled. A 16 cm³ volumetric imaging slab was prescribed immediately above the labeling plane. ASL parameters include: labeling duration 3 s; matrix size 160 x160 ; 3D isotropic resolution 1 mm; readout bandwidth 31.25 kHz; TR/TE (ms) 590/0.016; fractional echo 1; flip angle 4º. The scan time was 6:56 min.

Images from both 3D TOF and "Quiet" ASL MRA was presented, on a commercial imaging workstation, to one experienced neuroradiologist who qualitatively the images. The grading was not blinded as the 3D TOF and "Quiet" ASL exams can be readily distinguished by the presence or absence of slab artifact and residual background signal on the 3D TOF studies. 3D TOF and "Quiet" ASL MRA examinations were evaluated using three criteria: vessel segment visualization, saturation effect, and luminal uniformity (Table 1). Four vessel segments were evaluated for each subjects (segment precavernous =1, cavernous= 2, clinoid= 3, distal= 4) (fig. 1)

A non-parametric paired Wilcoxon test was used to compare the following parameters between 3DTOF and "Quiet" ASL MRA: quality of the vessel segment visualization, luminal rendering uniformity, and saturation effect. Statistical analysis was performed using commercially available software (SPSS version 20). A p < 0.05 indicated a statistically significant difference.

Images for this section:
<table>
<thead>
<tr>
<th>Criterion</th>
<th>Interpretation</th>
<th>Score</th>
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<tbody>
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<td>Image quality of the vessel segment visualization</td>
<td>Much less than expected</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Slightly less than expected</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Equal than expected</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Slightly better than expected</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Much better than expected</td>
<td>5</td>
</tr>
<tr>
<td>Luminal rendering uniformity</td>
<td>Sever inhomogeneity</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Slightly inhomogeneity</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Ideal</td>
<td>3</td>
</tr>
<tr>
<td>Saturation Effect</td>
<td>Sever</td>
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</tr>
<tr>
<td></td>
<td>Mild</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Non</td>
<td>3</td>
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**Table 1:** Criteria for qualitative evaluation
Results

Preliminary Results:

When the total vessel was evaluated (four segments) a higher mean image quality score was found for 3D TOF in comparison with "Quiet" ASL MRA (p=0.04). No significant differences in the means scores for the complete vessel were found for saturation effect and luminal rendering uniformity between the two sequences (Table 1).

When a segment vessel analysis was performed, a higher mean image quality score was found for 3D TOF that with "Quiet" ASL for segment 3 (clinoid segment). For all the other vessel segments (segment 1, 2, 4) no significant differences were found for image quality, saturation effect and luminal rendering uniformity between the two techniques.

"Quiet" ASL MRA was slightly better in the segment 2 for image quality, saturation effect and luminal rendering uniformity that 3D TOF. However, there was no statistically significant difference between the two methods in any of these groups.

Images for this section:
Fig. 2: Sagittal MIP images of "Quiet" ASL MRA and 3D TOF demonstrate "Quiet" ASL MRA seems to be superior in image quality to conventional 3D TOF for proximal artery. For distal artery, 3DTOF is still better.
<table>
<thead>
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<th></th>
<th>3D-TOF</th>
<th>ASL</th>
<th>p</th>
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<tr>
<td>Image Quality</td>
<td>2.87 ± 0.34</td>
<td>2.31 ± 1.1</td>
<td>0.04</td>
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<tr>
<td>Saturation Effect</td>
<td>2.62 ± 0.5</td>
<td>2.19 ± 0.98</td>
<td>0.08</td>
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<tr>
<td>Luminal rendering uniformity</td>
<td>2.50 ± 0.51</td>
<td>2.06 ± 0.9</td>
<td>0.1</td>
</tr>
</tbody>
</table>

**Table 2**
Fig. 1: AP view (A) MIP of "Quiet" ASL MRA and (B) MIP of 3D TOF. Images show complete filling of the entire arterial vasculature of the brain. Signal intensity decreases from proximal to distal vessels.
**Conclusion**

"Quiet" ASL MRA seems to produce superior image quality to conventional 3D TOF acquisitions with a lower tendency to turbulence related signal loss for proximal artery. For distal artery, 3DTOF is still better due to high signal noise ratio and high resolution.

"Quiet" ASL MRA provides superior image quality for proximal artery at reduced sound pressure levels and can be used as an additional method beside conventional 3D TOF for routine MRA of the brain.

**References**


**Personal Information**

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