Quiet PROPELLER MR Techniques Provide Equivalent Quality for Routine Brain MRI

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Purpose

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). It is been reported temporary shifts in hearing thresholds 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 procedure (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, and echo time.

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 work-place (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. New technology has made quieter techniques feasible which range from as low as 80 dB (1/10000 as loud) to nearly silent.

"Quiet" PROPELLER uses a standard 2D PROPELLER sampling scheme. The k-space trajectory and data sampling scheme can be optimized such that gradient steps are smaller than those in product PROPELLER and result in a scan that produces less noise than product.

This "Quiet" method reduces acoustic noise levels approximately 25-30dB for T2 PROPELLER and T2 FLAIR PROPELLER employing an acoustic noise model to optimize gradient waveforms while minimizing the impact on scan time. An additional 180º preparation is used to minimize the effect on image quality.

The purpose of this study is to evaluate the quality of "Quiet" MR FSE acquisitions in comparison to techniques in current day to day practice in imaging of the brain.
Methods and Materials

This is an on-going trial prospective study. Our aim is to include 50 subjects in this project. Subjects will be scanned with the "Quiet" T2 PROPELLER and "Quiet" T2 FLAIR PROPELLER technique in addition to conventional T2 PROPELLER and T2 FLAIR PROPELLER on a 1.5T MR.

To date, 8 subjects have been included. 2 healthy volunteers (two men, age range 26-45) and 6 patients (three women, three men, age range 79-34) diagnosed with stroke (n=2), headache (n=1), multiple sclerosis (n=1), metastatic disease (n=1) and first episode of psychosis (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 a 32-channel head coil (24 elements are activated). Subjects were imaged with a clinical standard T2 PROPELLER and T2 FLAIR PROPELLER scan and with "Quiet" FSE PROPELLER techniques.

The standard T2 PROPELLER scan was acquired with the following parameters: TR/TE 3066ms/99ms; field of view 22 x 22 cm; matrix 320x320; slice thickness 5 mm and slice spacing of 0 mm; Number of slice 30; Refocus flip angle 160º; bandwidth 50 kHz; Echo Train Length 28; Number of excitation 1.7; Acceleration factor 2; Scan time 1.26 minutes.

The standard T2 FLAIR PROPELLER scan was acquired with the following parameters: TR/TE 9500ms/109ms; TI 2250ms; field of view 23 x 23 cm; matrix 288 x 288, slice thickness 5 mm and slice spacing of 0 mm; Number of slice 30; Refocus flip angle 160º; bandwidth 62.5 kHz; Echo Train Length 32; Number of excitation 1.7; Acceleration factor 2; Scan time 3.10 minutes.

For the "Quiet" T2 PROPELLER scan, the protocol set was: TR/TE 6380ms/98ms; FOV = 22 x 22 cm; matrix of 320 X 320; 5mm slice thickness and slice spacing of 0 mm; Number of slice 30; bandwidth = 41KHz; refocus flip angle = 160º; Echo Train Length 16; Number of excitation 1.5; Acceleration factor 2; Scan time 2.16 minutes.

The "Quiet" T2 FLAIR PROPELLER protocol set was: TR/TE 9500ms/105ms; TI 2250ms; FOV = 23 x 23 cm, matrix of 288 X 288; 5mm slice thickness and slice spacing of 0 mm; Number of slice 30; bandwidth = 41KHz; refocus flip angle = 160º; Echo Train Length 18; Number of excitation 1.5; Acceleration factor 2; Scan time 5.20 minutes.
Images from both "Quiet" T2 PROPELLER and "Quiet" T2 FLAIR PROPELLER, together with conventional PROPELLER sequences were presented, on a radiology workstation, to an experienced neuroradiologist, who assessed the images quantitatively and qualitatively. The reader was blinded to the exams.

To assess the four different sequences quantitatively, a region of interest (ROI), measuring 10 mm$^2$, was placed on the periventricular white matter at the level of left lateral ventricle avoiding lesions and artifacts. ROI was placed on one MRI sequence and then automatically propagated to the other three.

"Quiet" T2 PROPELLER, "Quiet" T2 FLAIR PROPELLER and conventional T2 and FLAIR PROPELLER MR images were evaluated qualitatively using 3 criteria: overall quality, differentiation between grey and white matter and blurring perception (Table 1).

Additionally, the observer was asked to rank the images ("Quiet" T2 PROPELLER and "Quiet" T2 FLAIR PROPELLER and conventional T2 and FLAIR PROPELLER MR images) in order of preference and declare images as either better, worse, or equal to each other (overall preference).

A non-parametric paired Wilcoxon test was used to compare the quantitative and qualitative parameters. The results were express in mean standard deviation (mean SD). Statistical analysis was performed using commercially available software (SPSS version 20). A p < 0.05 indicated a statistically significant difference.
### Table 1: Criteria for qualitative evaluation

<table>
<thead>
<tr>
<th>Criterion</th>
<th>Interpretation</th>
<th>Score</th>
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<td>Overall quality</td>
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<tr>
<td></td>
<td>Quality as expected</td>
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</tr>
<tr>
<td></td>
<td>Better than expected</td>
<td>3</td>
</tr>
<tr>
<td>Grey-White Matter</td>
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</tr>
<tr>
<td>differentiation</td>
<td>Differentiation as expected</td>
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<tr>
<td></td>
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<tr>
<td>Blurring perception</td>
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<td>1</td>
</tr>
<tr>
<td></td>
<td>No</td>
<td>2</td>
</tr>
</tbody>
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Results

Preliminary Results:

Quantitative analysis

ROIs were successfully measured for 9 subjects. The mean SD in the white matter parenchyma on conventional T2 PROPELLER was 25.94 ± 6.8, and "Quiet" T2 PROPELLER was 24.6 ± 5.7. No significant difference in the mean SD was identified between the two sequences (p = 0.17). The mean SD in the white matter parenchyma on conventional T2 FLAIR PROPELLER (21.94 ± 5.69) was significantly higher in comparison to the "Quiet" T2 FLAIR PROPELLER sequences (18.6 ± 4.8) (p<0.02).

Qualitative analysis

No differences were observed in image quality, white/grey matter differentiation or blurring perception, between "Quiet" and conventional techniques for all the patients.

When the overall preference was evaluated no differences were found in all the cases between "Quiet" and conventional sequences. In only one case the "Quiet" T2 FLAIR PROPELLER was preferred over the conventional T2 FLAIR PROPELLER.
Images for this section:

Fig. 1: Case 1.

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Fig. 2: Case 2

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"Quiet" T2 PROPELLER and "Quiet" T2 FLAIR PROPELLER were comparable in quality to conventional PROPELLER acquisitions with no significant tradeoffs aside from longer scan times.

"Quiet" PROPELLER T2 and "Quiet" T2 FLAIR PROPELLER provide equivalent quality at comfortable sound pressure levels and can replace conventional sequences for routine evaluations of the brain.
References


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