Acoustic noise reduction in MRI using Silent Scan: an initial experience

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PURPOSE
Acoustic noise during magnetic resonance imaging (MRI) is the main source for patient discomfort and leads to verbal communication problems, difficulties in sedation, and hearing impairment. Silent Scan technology uses less changes in gradient excitation levels, which is directly related to noise levels. Here, we report our preliminary experience with this technique in neuroimaging with regard to subjective and objective noise levels and image quality.

MATERIALS AND METHODS
Ten patients underwent routine brain MRI with 3 Tesla MR750w system and 12-channel head coil. T1-weighted gradient echo (BRAVO) and Silenz pulse sequence (TE=0, 3D radial center-out k-space filling and data sampling with relatively small gradient steps) were performed. Patients rated subjective sound impression for both sequences on a 6-point scale. Objective sound level measurements were performed with a dedicated device in gantry at different operation modes. Image quality was subjectively assessed in consensus by two radiologists on a 3-point scale.

RESULTS
Readers rated image quality as fully diagnostic in all patients. Measured mean noise was reduced significantly with Silenz sequence (68.8 dB vs. 104.65 dB with BRAVO, \( P = 0.024 \)) corresponding to 34.3% reduction in sound intensity and 99.97% reduction in sound pressure. No significant difference was observed between Silenz sound levels and ambient sounds (i.e., background noise in the scanner room, 68.8 dB vs. 68.73 dB, \( P = 0.5 \)). The patients' subjective sound level score was lower for Silenz compared with conventional sequence (1.1 vs. 2.3, \( P = 0.003 \)).

CONCLUSION
T1-weighted Silent Scan is a promising technique for acoustic noise reduction and improved patient comfort.
density. The Silenz pulse sequence uses a 3D radial center-out sampling scheme where endpoints of each spoke follow a spiral path in time. Isotropic voxels are acquired with TE=0. An inversion preparation pulse is used to generate T1-weighted images. The gradient steps which are used in this sequence are relatively small in contrast to classic repetitive gradient ramp up and down steps during gradient-echo sequences.

**Data acquisition**

Data were acquired on a 3 T Discovery 750w MR scanner (General Electric Healthcare) using a 12-channel head coil array. Silenz sequence acquisition and k-space filling scheme is shown in Fig. 1. Acquired images were compared with a conventional T1-weighted 3D gradient echo sequence (BRAVO) with similar image contrast obtained in the same MRI session. Field of view, slice thickness, matrix and TI were identical in both sequences, while TR, TE and NEX for BRAVO were 8.2 ms, 3.1 ms, 1 ms, respectively. Silent Scan prototype software uses offline data reconstruction mode and system is halted during this process. To avoid potential delays of routine MRI session or technical issues with unexpected data loss, Silenz was performed as the last sequence.

**Subjective and objective assessment of sound levels**

Each patient received a written survey before the MRI examination, where they were asked to rate subjective noise level experiences in prior MRI examinations on a scale of 0–5 (0, no noise to hear; 1, mild noise; 2, moderate noise; 3, loud noise; 4, very loud noise; 5, unacceptable noise/cancellation of MRI). During the MRI examination, patients were informed by the built-in speaker system at the beginning and completion of Silenz sequence. After the scan, patients were asked to rate the Silenz sound experience on the same scale.

Objective sound level measurements were performed with a sound level meter (Bruel and Kjaer, Type 2250 (accuracy, ±1 dBA), Nærum, Denmark) and a microphone (Bruel and Kjaer, Type 4189). The device was placed in the gantry at a position where the right ear of the patient is usually located (Fig. 2). Measurements were performed in the ambient mode (i.e., background noise in the scanner room with the fan of gantry on or off, without any scanning action), during the T1-weighted Silenz scan, and the BRAVO scan, which served as the gold standard. Results from three measurements, each lasting 30 seconds, were averaged for each operation mode. Wilcoxon test was used in the statistical analysis of noise level differences.

**Image quality**

Image quality of Silenz sequence was subjectively assessed in consensus by...
two radiologists (both board certified, with more than 10 years of experience in neuroradiology) on a 3-point scale (0, nondiagnostic images; 1, diagnostic image with limitations; 2, fully diagnostic). Assessed parameters included general visual image quality, image noise (compared to BRAVO), ability to differentiate gray-white matter, ability to delineate vascular structures or parenchymal lesions of any etiology if present, and presence of any artifacts. Although the order of Silenz vs. BRAVO could not be randomized and Silenz was performed as the last sequence in the MRI protocol, readers did not find evidence of subjective differences in contrast enhancement patterns.

Results
Subjective sound experience based on the written patients’ survey showed reduced mean sound level perception with Silenz compared with prior MRI experience (1.1±0.7 vs. 2.3±0.64, \( P = 0.003 \)) (Table 2). Objective mean acoustic noise levels in the ambient mode, and during Silenz and BRAVO sequences are shown in Table 3. Noise levels were significantly lower during Silenz sequence compared with BRAVO (68.8±0.11 dB vs. 104.65±0.28 dB, \( P = 0.024 \)), resulting in a 35.8 dB (34.3%) reduction in sound intensity. Since acoustic measurements are based on a logarithmic scale, the difference of 35.8 dB corresponds to more than 99.97% reduction in sound pressure. Acoustic measurements demonstrated no significant increase in sound levels during Silenz sequence compared with the ambient mode (68.8±0.11 dB vs. 68.73±0.07, increase of 0.07 dB, \( P = 0.5 \)).

Both readers assessed the image quality in all patients as fully diagnostic. No artifacts limiting image quality were noted, no difficulty in detecting and delineating anatomic structures was reported (e.g., ventricular margins, detected lesions, vascular structures such as cerebral arteries or vertebral/basilar artery). However, both readers stated that image noise appeared higher and signal-to-noise ratios appeared lower in the Silenz sequence. Sample images for Silenz and BRAVO sequences are shown in Fig. 3.

Table 2. Subjective noise levels on a 6-point scale

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<tr>
<th>Patient no.</th>
<th>Prior MRI sound score</th>
<th>Silenz sound score</th>
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Mean±SD: 2.3±0.64 vs. 1.1±0.7

Discussion
Despite recent technological advances in hardware and software of MRI, sound exposure during the scan is still the main drawback of MRI on patient surveys. Furthermore, newer and more powerful gradient systems, especially on 3 T scanners, create more noise during the MRI exam. Our preliminary results show that Silent Scan technology using Silenz T1-weighted sequence achieves diagnostic image quality in brain MRI, despite readers’ subjective impression of higher image noise levels compared to conventional sequence. Patients rated sound levels during Silenz sequence as significantly lower than conventional sequences, and objective measurements confirmed these results. Special patient groups such as pediatric patients, the elderly, as well as patients prone to motion due to an aversion to sound are likely to benefit from Silent Scan with reduced motion artifacts.

In the past different approaches to reduce the noise of MRI scans have been described in the literature. Active/
passive gradient shielding by enclosing gradient coil in a vacuum environment, rotating or changing gradient fields mechanically, use of limited bandwidth pulse sequences or selective gradient derating have been described to reduce noise levels significantly (6–8). These techniques mainly focus on either shielding the generated noise or manipulating the gradient systems; however, none of them can reach the ambient sound levels yet. Silent Scan technology uses a different approach where gradients are used continuously at almost stable levels and changed in very small steps, resulting in almost no additional noise during MRI, compared with the ambient sound. Additionally, some hardware changes (e.g., coil) are used to optimize the results, enable zero TE, and allow extreme fast changes between receive and transmit modes of the used coil.

To the best of our knowledge, this is the first report regarding the Silent Scan technology in the literature. This preliminary study suffers from a few limitations. Number of patients is relatively low (n=10). Assessment of Silent Scan technology consisted of T1-weighted sequence only. Objective image quality measurements were not performed, since our aim was to test this new technique and determine its feasibility for clinical use before initiating further studies with larger numbers of patients. Beyond these initial results, further prospective randomized studies are needed on the product version of Silenz, which includes T2, T2 FLAIR, and MR angiography, in addition to T1-weighted sequence. Objective image quality assessment (i.e., background image noise, signal-to-noise and contrast-to-noise ratios, lesion conspicuity and ability to delineate) and scan times need to be compared with conventional sequences in order to evaluate advantages and potential drawbacks of this technique.

In conclusion, objective and subjective assessment of acoustic noise levels confirm reduced sound levels with Silent Scan technology using T1-weighted Silenz sequence. Special patient groups, such as pediatric, geriatric, and noncooperative patients, are expected to benefit from MRI at ambient sound levels. Further prospective randomized studies with larger series and diverse disorders are warranted.

**Conflict of interest disclosure**

S.A. reported receiving personal fees from GE Healthcare during the conduct of the study, as well as personal fees from Siemens Healthcare that are unrelated to the published work. M.V., W.S., D.W., C.A.B. and M.B. are employees of GE Healthcare.

**References**