Diagn Interv Radiol 2014; 20:360-363

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

Sedat Alibek, Mika Vogel, Wei Sun, David Winkler, Christopher A. Baker, Michael Burke, Hubertus Gloger

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.

Acoustic noise during magnetic resonance imaging (MRI) is one of the main sources of patient complaints and discomfort. Evidence from the scientific literature suggests that neonates may have an increased response to acoustic noise, elderly and pediatric patients may be confused due to MRI acoustic noise, sedated patients may experience additional discomfort due to high noise levels, and certain drugs may increase hearing sensitivity (1). Acoustic noise produced by the magnetic resonance (MR) scanner itself may have an influence on speech understanding during the exam, making communication with the patient difficult (2). Studies show that the use of headphones in patients under general anesthesia during MRI reduces spontaneous arm and leg movements significantly (3). Temporary shifts in hearing thresholds were reported in patients scanned without ear protection (4). Thus, reduction of the acoustic noise can increase patient comfort during MRI, and acceptance of the procedure may be increased. As involuntary patient movements and temporary hearing problems would be reduced, image quality is expected to improve when MR acoustic noise is reduced. Recently a new technology called Silent Scan, using a new prototype Silenz pulse sequence, has been introduced for brain imaging. Our aim is to report our initial experiences with this technology, focusing on acoustic noise levels and image quality.

Materials and methods

Patient population

The study population included 10 patients (eight females, two males; age range, 31–77 years; median, 56 years) referred to brain MRI with various indications (Table 1). Local ethics committee approved the study, and written informed consent was obtained from each subject. Standard sequences (i.e., T2 fluid attenuated inversion recovery [FLAIR], T2, diffusion-weighted imaging, T2*, T1 brain volume imaging [BRAVO], time of flight MR-angiography) were obtained according to the clinical indication. In four patients additional T1-weighted images were acquired after manual intravenous injection of gadolinium-based contrast agent at a dose of 0.2 mL/kg bodyweight.

Silenz pulse sequence

Silenz pulse sequence was installed as a prototype version on our 3 Tesla (T) wide-bore scanner (Discovery MR750w, General Electric Healthcare, Milwaukee, Wisconsin, USA) on March 2013 and a feasibility study was initiated. Silenz (General Electric Healthcare) is based on a 3D gradient-echo imaging technique with a very short TE and low flip angles (5). The inherent contrast without any preparatory pulses is similar to proton

MVZ Radiologie & Nuklearmedizin (S.A. ✉ *dr.s.alibek@t-online.de*, H.G.), Fürth, Germany; General Electric Healthcare (M.V., M.B.), Buc, France; General Electric Healthcare (W.S., D.W., C.A.B.), Milwaukee, Wisconsin, USA.

Received 13 November 2013; revision requested 18 November 2013; final revision received 27 November 2013; accepted 4 December 2013.

Published online 29 April 2014.
DOI 10.5152/dir.2014.13458

Table 1. Demographic patient data with referring clinical diagnosis and MRI findings

Patient no.	Age	Gender	Referring diagnosis	MRI findings
1	73	F	Rule out ischemic changes	Chronic ischemic changes
2	62	F	Persistent headache, auditory deficits	No abnormality
3	72	F	Dizziness, history of breast carcinoma, rule out metastasis	No abnormality
4	48	M	Persistent headache	No abnormality
5	77	F	History of fall and breast carcinoma, rule out metastasis	Chronic ischemic changes
6	65	F	History of fall and breast carcinoma, rule out metastasis	Chronic ischemic changes
7	31	F	Sensory deficit, rule out encephalomyelitis disseminata	No abnormality
8	50	F	Visual disturbance, right eye	No abnormality
9	48	M	Facial paresis, right side	No abnormality
10	48	F	Dizziness, history of loss of consciousness	No abnormality

F, female; M, male.

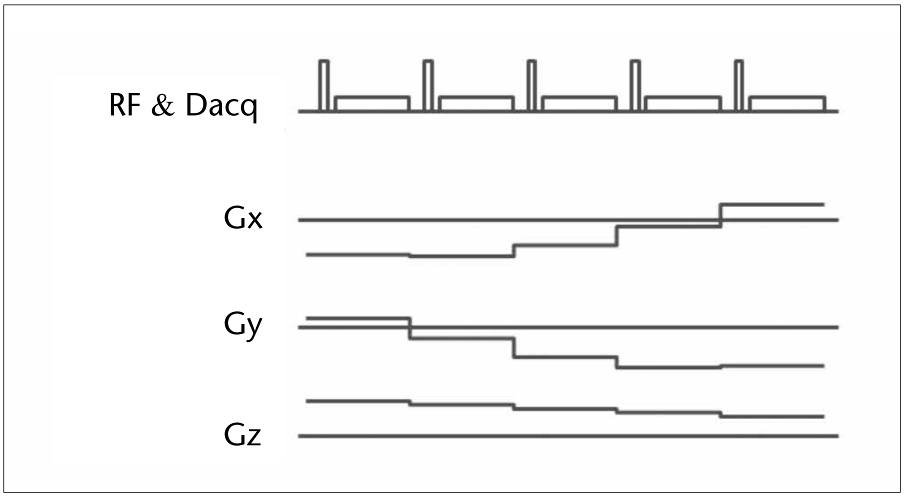

Figure 1. Silenz acquisition and k-space readout scheme. Silenz uses a 3D radial center-out data acquisition scheme between radio frequency pulses (RF), stepping through k-space by increasing gradients in small steps. Ramp-up and ramp-down of gradients (Gx, Gy, Gz) between spokes are eliminated, resulting in the silent properties of the pulse sequence.

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. Imaging parameters for Silenz T1-weighted pulse sequence were as follows: TR, 990 ms; TE, 0 ms; TI, 450 ms; slice thickness, 1 mm; matrix, 256×256; field of view, 25.6 cm; flip angle, 4°; number of excitations (NEX), 1.5; bandwidth, 31.25 kHz. Three-dimensional data were acquired in the sagittal orientation. The number of slices was adjusted to cover the patients head. This setup resulted in a data acquisition time of about 254 s. 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.

Figure 2. The sound level meter is placed in the gantry at a position corresponding to the right ear of the patient.

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

Patient no.	Prior MRI sound score	Silenz sound score
1	3	2
2	2	0
3	2	2
4	3	2
5	3	1
6	2	1
7	2	1
8	2	1
9	3	1
10	1	0
Mean±SD	2.3±0.64	1.1±0.7

SD, standard deviation.

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/

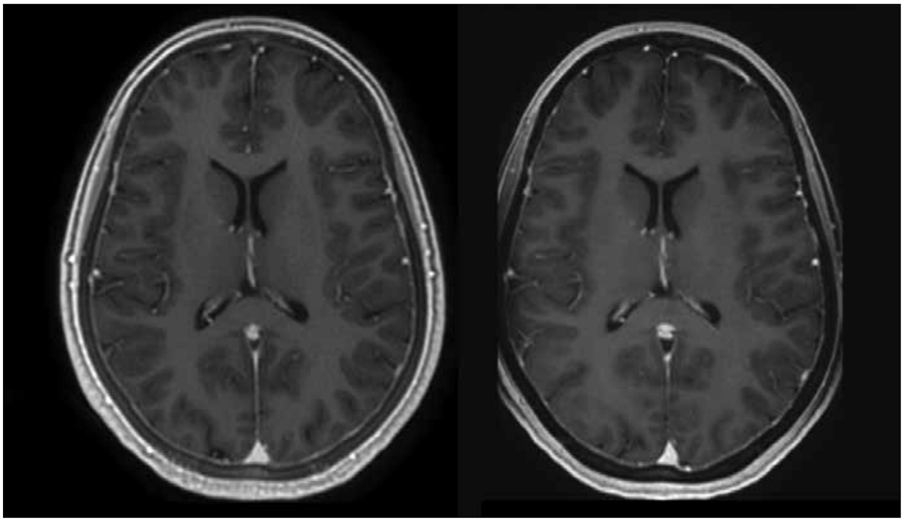

Figure 3. Silenz vs. BRAVO image. Contrast enhanced sample image from a 3D T1-weighted Silenz scan (left) and 3D BRAVO scan (right) are shown (screenshots from a transverse reconstruction of 3D source images).

Table 3. Mean noise levels during T1-weighted Silenz and BRAVO sequences

Sound measurements	Sound level (dB)
Ambient (gantry fan on)	72.55±0.48
Ambient (gantry fan off)	68.73±0.07
T1-weighted Silenz	68.8±0.11
T1 BRAVO	104.65±0.28

Ambient refers to the background noise level in the scanner room.
Data are given as mean±standard deviation.

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

1. McJury M, Shellock FG. Auditory noise associated with MR procedures: a review. J Magn Reson Imaging 2000; 12:37–45. [CrossRef]
2. Moelker A, Maas RAJJ, Pattynama PMT. Verbal communication in MR environments: effect of MR system acoustic noise on speech understanding. Radiology 2004; 232:107–113. [CrossRef]
3. Ogurlu M, Orhan ME, Cinar S, et al. Effect of headphones on sevoflurane requirement for MRI. Pediatr Radiology 2012; 42:1432–1436. [CrossRef]
4. Brummett RE, Talbot JM, Charuhas P. Potential hearing loss resulting from MR imaging. Radiology 1988; 169:539–540.
5. Madio DP, Lowe IJ. Ultra-fast imaging using low flip angles and FIDs. Magn Reson Med 1995; 34:525–529. [CrossRef]
6. Edelstein WA, Kidane TK, Taracila V et al. Active-passive gradient shielding for MRI acoustic noise reduction. Magn Reson Med 2005; 53:1013–1017. [CrossRef]
7. Zhou Y, Ma J. Acoustic noise reduction in MRI. Paper presented at: 2010 Annual Meeting & Exhibition of International Society of Magnetic Resonance Imaging in Medicine: May 1–6, 2010; Stockholm, Sweden.
8. Pierre EY, Grodzki D, Heismann B et al. Reduction of acoustic noise to improve patient comfort through optimized sequence design. Paper presented at: 2013 Annual Meeting & Exhibition of International Society of Magnetic Resonance Imaging in Medicine: April 20–26, 2013; Salt Lake City, Utah, USA.