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MR Imaging of the Facial Nerve through the Temporal Bone at 3T with a Noncontrast Ultrashort Echo Time Sequence

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ABSTRACT

SUMMARY: The pointwise encoding time reduction with radial acquisition (PETRA) ultrashort echo time MR imaging sequence at 3T enables visualization of the facial nerve from the brain stem, through the temporal bone, to the stylomastoid foramen without intravenous contrast. Use of the PETRA sequence, or other ultrashort echo time sequences, should be considered in the MR imaging evaluation of certain skull base tumors and perhaps other facial nerve and temporal bone pathologies.

ABBREVIATIONS: CNR = contrast-to-noise ratio; IR-FSPGR = inversion recovery-prepared fast spoiled gradient recalled-echo; PETRA = pointwise encoding time reduction with radial acquisition; UTE = ultrashort echo time

The cisternal, canalicular, labyrinthine, geniculate, tympanic, and mastoid segments of the facial nerve are either not detectable or only faintly visible on noncontrast T1-weighted MR images.¹ Moreover, although contrast enhancement of the surrounding venous plexus can aid in facial nerve visualization, the extent of enhancement is variable and unreliable.² We hypothesized that visibility of the facial nerve could be improved with ultrashort echo time (UTE) imaging. UTE sequences capture signal from rapidly decaying short-T2 tissue, such as cortical bone³ and middle ear ossicles⁴ and, therefore, should capture signal from the petrous and mastoid portions of the temporal bone. Moreover, peripheral nerves have detectable signal in the ultrashort T2 spectrum,⁵ so UTE imaging should provide visualization of the facial nerve. Finally, UTE imaging minimizes air-related susceptibility artifacts⁶ and would therefore minimize artifacts from the middle ear cavity and mastoid air cells that may contribute to nonvisualization of the facial nerve on spin-echo and gradient-echo sequences. The pointwise encoding time reduction with radial acquisition (PETRA) UTE sequence provides more con-

sistent image quality over a wider range of conditions than similar sequences.⁷ This report describes the evaluation of the facial nerve segments through the temporal bone using both the default PETRA protocol and a shortened 4-minute PETRA protocol.

MATERIALS AND METHODS

As part of a prospective study designed to evaluate the extracranial facial nerve, an MR imaging examination of the brain and face that included a PETRA sequence was performed in 8 healthy subjects (6 men, 2 women; 31 ± 8 years of age) between January and March 2018. All subjects provided informed consent. The study was approved by our institutional review board and performed in compliance with the Health Insurance Portability and Accountability Act.

Imaging Protocols

All imaging was performed on a Magnetom Prisma 3T MR imaging system with a 64-channel head/neck coil (Siemens, Erlangen, Germany). The default PETRA protocol as installed by Siemens (Table 1) was performed on 7 subjects and 14 facial nerves. Due to the 6-minute duration of the protocol, parameter modifications were tested to reduce imaging time while retaining the signal-to-noise ratio and contrast-to-noise ratio (CNR) of the facial nerve and surrounding structures. A modified 4-minute protocol (Table 1) was performed on 5 subjects and 10 facial nerves. Imaging with both PETRA protocols was performed on 4 subjects.

Imaging Analysis

Two independent reviewers scored the visibility of the cisternal, canalicular, labyrinthine, geniculate, tympanic, and mastoid seg-

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ments of the facial nerve and the greater superficial petrosal nerve on each side of each subject on all series of default PETRA and 4-minute PETRA images. One reviewer was a neuroradiologist with 10 years' attending-level experience, and 1 reviewer was a postgraduate year-5 radiology resident completing a year-long neuroradiology mini-fellowship. To allow indirect comparison with a prior study that evaluated these facial nerve segments using a 3D inversion recovery fast spoiled gradient recalled (IR-FSPGR) sequence,¹ we scored the signal intensity as follows: 0, no signal; 1, faint visualization; 2, signal equivalent to that of the normal cer-

bellum. The scored data from both reviewers were summed and averaged for each facial nerve segment for both the default PETRA and 4-minute PETRA images. Using sample size, means, and SDs, we calculated independent-sample *t* tests to compare the signal intensity of the facial nerve on the 4-minute PETRA protocol images, as scored for this study, with the signal intensity of the facial nerve on the IR-FSPGR images, as scored in the study by Dehkharghani et al.¹

To determine the SNR and CNR, in all 4 subjects in whom both protocols were performed, we drew ROIs on a single slice over the following structures of the default and 4-minute PETRA images: facial nerve tympanic segment, ossicle, middle ear cavity, mastoid, brain stem, and extracorporeal background region lateral to the temporal bone. The SNR and CNR were calculated as follows: SNR = Mean Signal Intensity of the Region/SD of Background Noise; CNR = SNR Region 1 – SNR Region 2.

RESULTS

All evaluated segments of the facial nerve were visible by both reviewers (Figure) with a score of either 1 or 2 with 90.5% overall reviewer agreement. The signal intensity of all facial nerve segments was significantly greater for the 4-minute PETRA protocol images compared the IR-FSPGR images (Table 2).

SNR and CNR values were consistently similar or higher with the 4-minute PETRA protocol compared with the default PETRA protocol (Tables 3 and 4).

DISCUSSION

This study demonstrates that noncontrast UTE imaging with the PETRA sequence can provide visualization of the facial nerve from the brain stem to the stylomastoid foramen. Such visualization is not possible with more routine sequences currently used in skull base or internal auditory canal imaging.^{1,2} The PETRA sequence is a proved alternative to an IR-FSPGR sequence in pediatric brain imaging⁸ and could perhaps similarly substitute for IR-FSPGR sequences in skull base imaging.

It is known that ultrashort T2 (<1 ms) MR signal can be detected in peripheral nerves and imaged. This signal originates from protons in myelin phospholipids⁵ and likely accounts, at least in part, for the consistent visibility of the facial nerve with the PETRA sequence. In addition, it is likely that artifacts related to the air/tissue interfaces in the temporal bone interfere with detection of signal from the facial nerve on more routine sequences. Minimization of air-related susceptibility artifacts with the

Table 1: Parameters for default and 4-minute PETRA sequences

	Default	4-Minute
TR 1	3.32 ms	3.32 ms
TR 2	2250 ms	2250 ms
TE	0.07 ms	0.07 ms
TI	1300 ms	2000 ms
TI 2	900 ms	900 ms
Averages	1	1
Slice thickness	0.9 mm	0.9 mm
FOV	300 × 300	300 × 300
Matrix	320 × 320	320 × 320
Voxel size	0.9 × 0.9 × 0.9 mm	0.9 × 0.9 × 0.9 mm
Bandwidth	400 kHz	400 kHz
Flip angle	6°	6°
Radial views	60,000	40,000
Acquisition time	5:57 minutes	4:05 minutes

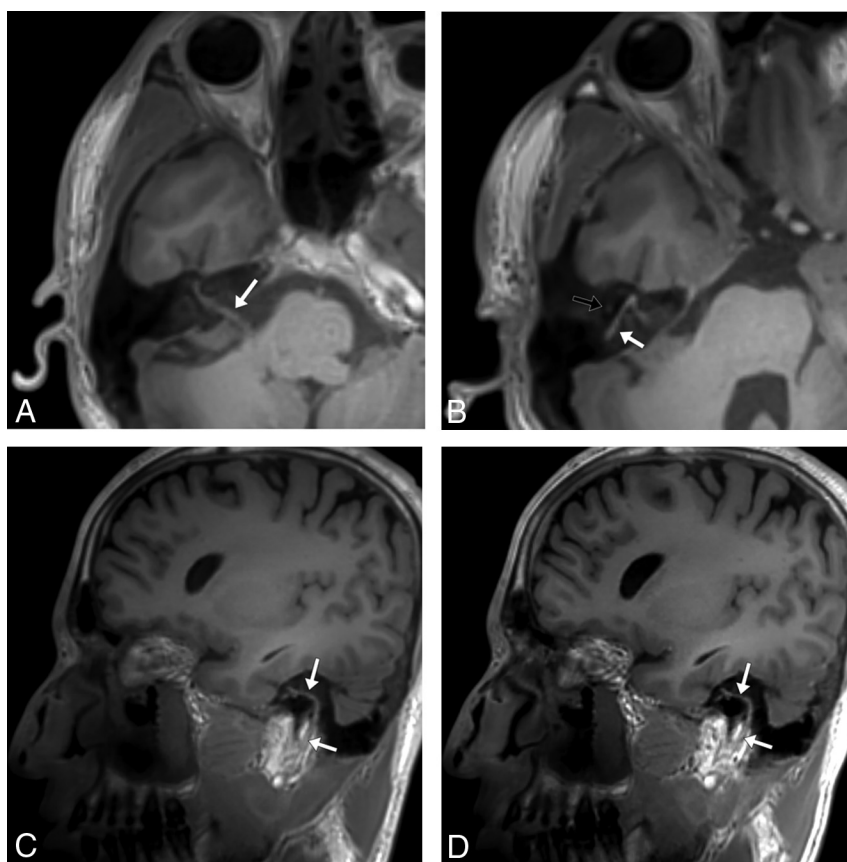


FIGURE. Normal right facial nerve in a 27-year-old healthy female volunteer. Axial oblique (A and B) and sagittal oblique (C and D) noncontrast MR images obtained with the 4-minute PETRA protocol show the cisternal, canalicular, labyrinthine, geniculate, tympanic, and mastoid segments of the right facial nerve (white arrows) and a portion of an ossicle (black arrow). D, Sagittal oblique image obtained with the default PETRA protocol shows a slightly sharper but similar appearance to C.

Table 2: Signal intensity comparison of PETRA and IR-FSPGR sequences as previously reported^a

	Default PETRA	4-Minute PETRA	IR-FSPGR (from Dehkharghani et al ¹)	P Value (4-Minute PETRA vs IR-FSPGR)
Cisternal	1.89 (0.31)	2.00 (0.00)	0.86 (0.42)	<.001
Canalicular	1.86 (0.36)	2.00 (0.00)	0.83 (0.44)	<.001
Labyrinthine	1.79 (0.42)	1.85 (0.37)	0.88 (0.39)	<.001
Geniculate	2.00 (0.00)	2.00 (0.00)	1.03 (0.22)	<.001
Tympanic	1.96 (0.19)	2.00 (0.00)	0.95 (0.32)	<.001
Superficial Petrosal	2.00 (0.00)	2.00 (0.00)	0.96 (0.30)	<.001
Mastoid	2.00 (0.00)	2.00 (0.00)	1.01 (0.30)	<.001

^a To allow direct comparison with the data published by Dehkharghani et al,¹ except for the *P* values, we report data as mean (SD) of assigned signal intensity, in which each facial nerve segment was assigned a value of 0–2 (0, no detectable signal; 1, faint visualization; 2, signal equivalent to normal brain).

Table 3: Signal-to-noise ratio for default and 4-minute PETRA sequences

	Subject C		Subject D		Subject F		Subject G	
	Default PETRA	4-Minute PETRA	Default PETRA	4-Minute PETRA	Default PETRA	4-Minute PETRA	Default PETRA	4-Minute PETRA
Facial nerve	125	165	113	159	88	140	99	173
Ossicle	58	116	65	114	39	94	57	118
Middle ear	5	51	31	75	36	83	14	59
Mastoid	36	55	62	106	28	54	42	63
Brain stem	168	281	155	290	151	277	176	300

Table 4: Contrast-to-noise ratio for default and 4-minute PETRA sequences

	Subject C		Subject D		Subject F		Subject G	
	Default PETRA	4-Minute PETRA	Default PETRA	4-Minute PETRA	Default PETRA	4-Minute PETRA	Default PETRA	4-Minute PETRA
Facial nerve/mastoid	89	111	51	43	75	69	57	88
Facial nerve/middle ear	120	114	82	67	65	46	85	91
Ossicle/mastoid	22	62	3	7	13	32	15	44
Ossicle/middle ear	53	65	34	31	4	9	43	47

UTE sequences⁶ may reduce such interference and may also contribute to the consistent visibility of the facial nerve with the PETRA sequence. Comparison of temporal bone imaging with multiple different UTE sequences could help elucidate the biophysical properties that allow imaging of the facial nerve through the temporal bone and help optimize the technique.

The default PETRA protocol runs nearly 6 minutes. We shortened the protocol to 4 minutes by reducing the radial acquisitions from 60,000 to 40,000. To recover SNR and CNR, we increased the first TI, which is used in the pointwise acquisition of central *k*-space data.^{6,8} Our increase of the TI from 1300 to 2000 ms would be expected to increase signal in the brain and nerve tissues at some expense to gray and white matter contrast. These parameter changes resulted in mild signal artifacts in the middle ear cavity, demonstrated by higher middle ear cavity SNR.

The major limitation of this study is that imaging was performed with a single MR imaging system on a small sample of healthy subjects and does not prove reproducibility on other MR imaging systems or in a clinical setting. In addition, the comparison of signal intensities between PETRA and IR-FSPGR sequences was made across studies performed by different researchers with different subjects and equipment.

CONCLUSIONS

A 3T MR imaging 4-minute noncontrast PETRA protocol enables visualization of the facial nerve from the brain stem, through the temporal bone, to the stylomastoid foramen. Use of the PETRA sequence, or other UTE sequences, should be considered in the

MR imaging evaluation of certain skull base tumors and perhaps other facial nerve and temporal bone pathologies.

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