European Journal of Radiology 85 (2016) 2188–2194

Contents lists available at ScienceDirect

European Journal of Radiology

journal homepage: www.elsevier.com/locate/ejrad

Revisiting the relationship of three-dimensional fluid attenuation inversion recovery imaging and hearing outcomes in adults with idiopathic unilateral sudden sensorineural hearing loss☆

Wen-Huei Liao[a,b], Hsiu-Mei Wu[a,c], Hung-Yi Wu[c], Tzong-Yang Tu[a,b], An-Suey Shiao[a,b], Mauricio Castillo[d], Sheng-Che Hung[a,c,e,*]

[a] School of Medicine, National Yang Ming University, Taipei, 11221, Taiwan
[b] Department of Otolaryngology, Taipei Veterans General Hospital, Taipei, 11217, Taiwan
[c] Department of Radiology, Taipei Veterans General Hospital, Taipei, 11217, Taiwan
[d] Department of Radiology, University of North Carolina, Chapel Hill, NC, 27599-7510, USA
[e] Department of Biomedical Imaging and Radiological Sciences, National Yang Ming University, Taipei, 11221, Taiwan

ARTICLE INFO

Article history:
Received 8 July 2016
Received in revised form 2 September 2016
Accepted 7 October 2016

Keywords:
FLAIR
Sensorineural hearing loss
SNHL
MRI

ABSTRACT

Background and purpose: Three-dimensional fluid attenuation inversion recovery (3D FLAIR) may demonstrate high signal in the inner ears of patients with idiopathic sudden sensorineural hearing loss (ISSNHL), but the correlations of this finding with outcomes are still controversial. Here we compared 4 3D MRI sequences with the outcomes of patients with ISSNHL.

Materials and methods: 77 adult patients with ISSNHL underwent MRI with pre contrast FLAIR, fast imaging employing steady-state acquisition images (FIESTA-C), post contrast T1WI and post contrast FLAIR. The extent and degree of high signal in both cochleas were evaluated in all patients, and asymmetry ratios between the affected ears and the normal ones were calculated. The relationships among MRI findings, including extent and asymmetry of abnormal cochlear high signals, degree of FLAIR enhancement, and clinical information, including age, vestibular symptoms, baseline hearing loss, and final hearing outcomes were analyzed.

Results: 54 patients (28 men; age, 52.1 ± 15.5 years) were included in our study. Asymmetric cochlear signal intensities were more frequently observed in pre contrast and post contrast FLAIR (79.6% and 68.5%) than in FIESTA-C (61.1%) and T1WI (51.9%) ($p < 0.001$). Age, baseline hearing loss, extent of high signal and asymmetry ratios of pre contrast and post contrast FLAIR were all correlated with final hearing outcomes. In multivariate analysis, age and the extent of high signals were the most significant predictors of final hearing outcomes.

Conclusion: 3D FLAIR provides a higher sensitivity in detecting the asymmetric cochlear signal abnormality. The more asymmetric FLAIR signals and presence of high signals beyond cochlea indicated a poorer prognosis.

1. Introduction

Sudden sensorineural hearing loss is characterized by rapid progression of hearing impairment within seconds to days. This process is generally unilateral and may affect any age group but has a peak incidence during the 5th and 6th decades of life [1]. Bilateral involvement is rare and in most patients, sudden sensorineural hearing loss is idiopathic (ISSNHL) and probably multifactorial. The most common proposed etiologies include infections, trauma, vascular or hematologic causes and neoplastic [2]. In a recent study, over 95% of American neuro-otologists considered MRI a crucial examination to rule out intracranial mass lesions for all patients with ISSNHL [3]. However, such lesions are very uncommon, and

Abbreviations: dB, decibel; FIESTA-C, fast imaging employing steady-state acquisition images; FSPGR, fast spoiled gradient recall echo; ISSNHL, idiopathic sudden sensorineural hearing loss; ROC, receiver operating characteristic.

☆ Part of the materials had been presented in the Radiological Society of North America in 2015.

* Corresponding author at: Department of Radiology, Taipei Veterans General Hospital, Taipei, No.201, Sec. 2, Shipai Rd., Beitou District, Taipei City, 11217, Taiwan.
E-mail address: hsz829@gmail.com (S.-C. Hung).
URL: http://mailto:hsz829@gmail.com (S.-C. Hung).

http://dx.doi.org/10.1016/j.ejrad.2016.10.005
0720-048X/

Table 1
Modified Siegel's criteria of hearing recovery.

Grade	Hearing recovery
1. Complete Recovery	Final hearing better than 25 dB
2. Partial Recovery	More than 15 dB gain, final hearing 26–45 dB
3. Slight Recovery	More than 15 dB gain, final hearing 46–70 dB
4. No Improvement	Less than 15 dB gain, or final hearing 71–90 dB
5. Non-Serviceable ear	Final hearing poorer than 91 dB

MRI has a low positive rate (1–4%) [3]. This study aims to find if MRI can provide additional prognostic information from these otherwise unrevealing MRI studies.

Recently, non-contrast three-dimensional fluid-attenuated inversion recovery (3D FLAIR) was used to visualize the labyrinth and was able to detect abnormal high signal intensity in affected inner ear structures [4–11]. Previous studies show that 3D FLAIR improves detection of inner ear abnormal signal in patients with ISSNHL without other intracranial pathology based on pre contrast FLAIR only [12], post contrast FLAIR only [13], or both pre and post contrast FLAIR [4,6,9,10]. In a meta-analysis study [14], the group with high signal on pre contrast FLAIR tends to have worse initial hearing loss, and lower rate of hearing improvement than the group without high signal. However, the pooled hearing improvement in decibels was not significant, and the value of post contrast FLAIR is not known.

The purpose of our study was to explore the clinical implications of 3D FLAIR findings and hearing outcomes using both qualitative and quantitative approaches in patients with ISSNHL.

2. Materials and methods

2.1. Patients

From June 2013 to September 2014, 77 adult patients who presented with ISSNHL underwent contrast-enhanced MRI studies. Sudden sensorineural hearing loss was defined as per the American Academy of Otolaryngology–Head and Neck Surgery practice guidelines as follows: greater than 30-dB (dB) hearing loss occurring in at least 3 contiguous frequencies in less than 72 h without an obvious cause [15]. MRI studies and medical records were retrospectively analyzed. Our institutional review board approved this study.

According to the routes of steroid administration, the patients were also divided into three groups: group 1, intravenous dexamethasone 10 mg/day for 5 days and then tapered with oral methylprednisolone; group 2, intratympanic dexamethasone 5 mg/time per week or per month; group 3, combined concurrent intravenous dexamethasone 10 mg/day and intratympanic dexamethasone 5 mg/day for 5 days and then tapered with oral methylprednisolone. Whether hyperbaric oxygen therapy was given was also recorded. All patients underwent pure tone audiometry at presentation and thereafter at 3 and 6 months. The degree of hearing improvement was graded according to the modified Siegel's criteria (Table 1).

2.2. MRI studies

MRI studies were performed on one 1.5T scanner (Signa HDxt, GE Healthcare, Milwaukee, Wisconsin, USA), with an 8-element phased-array sensitivity-encoding head coil. Fast imaging employing steady-state acquisition images (3D FIESTA-C) were acquired for anatomic reference. Precontrast 3D FLAIR was obtained before injection of contrast medium. After intravenous administration of a single-dose (0.1 mmol/kg) of gadobutrol (Gadovist, Bayer Shering Pharma AG, Berlin, Germany), a 3D T1-weighted fast spoiled gradient recall echo (FSPGR), followed by 3D FLAIR were obtained (Table 2). The post contrast 3D FLAIR was obtained after the FSPGR, about 6–10 min after administration of contrast media.

2.3. Image analysis

2.3.1. Qualitative analysis

One experienced neuroradiologist, who was only aware of the side of involvement but blinded to the audiometric results, analyzed the images by comparing bilateral inner ears on both pre contrast and post contrast 3D FLAIR. All patients with other brain lesions were excluded. According to the location of increased signals, the extent of labyrinthine involvement was graded as grade 0, no visible abnormality; grade 1, high signal intensity in cochlea only; grade 2, high signal intensity in both cochlea and vestibule (Fig. 1).

2.3.2. Quantitative analysis

One blinded observer processed all images on a workstation (AZE Virtual Place Plus; AZE Corporation, Tokyo, Japan). First, the 3D FIESTA-C images were used for anatomic reference and the other 3 3D sequences were automatically realigned and registered to the 3D FIESTA-C for ROI drawing. One free-hand polygonal ROI was set manually to include as much of each cochlea as possible, at the mid-cochlear level and excluding the modiolus on the 3D FIESTA-C image. Then the ROI was mapped onto images of other sequences (Fig. 2). The asymmetry ratio was defined as the signal intensity ratio between the affected cochlea and unaffected contralateral cochlea. Findings were defined as asymmetric when the ratio was >1 in the 3D FLAIR and FSPGR images or <1 in 3D FIESTA-C images. The relative increase of FLAIR signals was defined as ΔFLAIR = (post contrast FLAIR – pre contrast FLAIR) of affected ear/pre contrast FLAIR of unaffected ear.

Another observer used the same method to measure the cochlear signal intensities of the first consecutive 20 patients. These measurements were used to calculate the interobserver reliability.

Table 2
Parameters of MRI sequences.

	3D FLAIR	3D FIESTA-C	3D FSPGR
Timing of acquisition	pre- & postcontrast	precontrast	postcontrast
Scan orientation	Sagittal	Axial	Axial
Slice thickness/gap (mm)	1/0	1/−0.5	1.5/0
TR (ms)	6000	4.275	3
TE (ms)	131.53	1.584	7.9
Inversion time (ms)	1852	0	400
Flip Angle (degree)	90	65	15
Field of view (mm)	256	240	240
Voxel size (mm)	0.5 × 0.5 × 1	0.47 × 0.47 × 1	0.94 × 0.94 × 1.5
Number of excitation	1	1	1