




# Extended High Frequency Audiometry for Revealing Sudden Sensory Neural Hearing Loss in Acute Tinnitus Patients

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## Abstract

**Introduction** The measurement of extended high-frequency (EHF) audiometry has become more popular recently, mainly in connection with ototoxicity and noise-induced hearing loss. New-onset tinnitus evaluation includes a standard hearing test that shows no pathology.

**Objective** The aim of the present study was to evaluate the possibility that acute tinnitus is essentially connected to sudden sensory neural hearing loss (SSNHL), by utilizing EHF audiometry in cases in which standard audiometry for frequencies between 250 Hz to 8 kHz is within normal limits.

**Methods** A retrospective study was conducted between January 2009 and May 2014 that included all patients presenting with acute tinnitus and normal standard audiometry. All patients underwent EHF audiometry and were treated accordingly.

**Results** Thirty-two patients with acute tinnitus and asymmetric sensorineural hearing loss on EHF audiometry were identified. The average deltas between the ears were between 9.2 and 33dB (worse in the affected ear).

**Conclusion** Extended high-frequency audiometry up to 20,000 Hz should be performed in all patients with acute tinnitus and standard audiometry within normal limits.

## Keywords

- ▶ extended high frequency audiometry
- ▶ sudden sensory neural hearing loss
- ▶ tinnitus

## Introduction

The most common method for assessment of hearing loss is pure-tone audiometry, which is performed at frequencies of 250 to 8,000 Hz. Recently, there has been an increasing interest in the measurement of auditory thresholds above 8000 Hz (the extended high frequency [EHF]). The measurement of the EHF range is facilitated by the development of audiometers capable of delivering sounds with sufficient pressure levels and earphones that can optimally transmit sound through the ear canal.<sup>1</sup> The EHF audiometry, although not validated for clinical use, is used to monitor patients

under a high risk of hearing loss. Although mainly used in research, EHF audiometry is also used in some clinical protocols to detect early changes to the auditory thresholds and to plan early intervention when possible. The clinical utility of EHF audiometry has newly been proposed for the monitoring of ototoxicity-induced hearing loss and the adverse effects of noise. The use of EHF audiometry to detect ototoxicity prior to involvement of the frequencies important for verbal communication has been reported.<sup>2</sup> The results of this study strengthen the need to serially monitor auditory thresholds, especially in the high-frequency range, of patients receiving ototoxic drugs. The use of EHF

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audiometry to detect noise-induced hearing loss is less established. Extended high frequency audiometry has been suggested as being more sensitive to detect noise-induced hearing loss in noisy occupational environments, especially in younger workers.<sup>3</sup> However, other studies have concluded that EHF audiometry has no additional value in predicting noise-induced hearing loss.<sup>4-6</sup> It is not unusual for patients with acute tinnitus to have standard audiometric evaluation that is within normal limits. However, these patients may have EHF hearing loss that may be missed on standard 250 to 8,000 Hz audiometry. In this study, we sought to examine cases of acute tinnitus with normal hearing between 250 to 8,000 Hz, and assess whether they may represent SSNHL based on EHF audiometry results.

## Materials and Methods

The present study was approved by the institutional review board.

In a retrospective study conducted between January 2009 and May 2014 at the Otolaryngology Head and Neck Surgery Department of the Assaf Harofeh Medical Center, all patients presenting with acute tinnitus were identified. Patients of all ages were included in our study. We included all patients who presented with: (1) previously normal hearing as reported by the patient; (2) audiometry confirmation of a 30-dB hearing loss at 3 consecutive frequencies within less than 72 hours from symptom evolvment; (3) absence of previous or active ear infections; (4) no previous history of noise exposure or phonal trauma; (5) no previous history of ototoxic medications; (6) no family history of hearing loss; and (7) no history of chronic tinnitus. All patients were examined in the Emergency Department and were subjected to careful ear examination to identify any abnormalities that might interfere with hearing, such as a tympanic membrane perforation or other middle ear abnormalities. All participants completed an audiologic evaluation including pure tone audiometry for the range 250 Hz to 8,000 Hz. In patients with normal symmetric hearing, the examination was extended to 20,000 Hz. Conventional frequency audiometry and EHF audiometry were conducted in a sound-treated room (MOD.AP30). The instrument used for the study was the Amplaïd A319 high frequency clinical audiometer (Amplifon, Milan, Italy) with standard TDH-49 headphones (Telephonics, New York, United states) used for the frequency range of 250 to 8,000 Hz, and Sennheiser HDA200 circumaural phones (Braunschweig, Germany) used to test the extended high frequency 8,000 to 20,000 Hz range. Measurements were made with an ascending-descending technique, in 5-dB steps in both conventional and EHF audiometry. All thresholds were calculated in dB HL. Audiologic tests were analyzed for asymmetric sensory neural hearing loss. Although audiometry confirmation of a 30-dB hearing loss at 3 consecutive frequencies within less than 72 hours from symptom evolvment was the definition of SSNHL in our study, a 10 dB difference between the 2 ears was recorded as asymmetric hearing. Audiograms were performed before commencing therapy. All patients with asymmetric sensorineural hearing loss were treated with an oral steroid (oral prednisone 1 mg/kg

for 7 days). In addition, average bone conduction thresholds in EHF were compared with reference thresholds.<sup>1</sup>

## Results

Our study population included 28 patients who complained of having new-onset tinnitus. The study consisted of 16 men and 12 women with a mean age of 41.5 years (10–69 years). Three children were identified during the study period. Comorbidities were detected in 7 patients, including: hypertension in 4 (14.5%) patients, hyperlipidemia in 2 (7%), and cerebrovascular accident in 1 (3.5%). The duration range of tinnitus prior to admission was 0 to 7 days (mean: 3.3 day). Nineteen (67%) patients complained of having ipsilateral hearing loss sensation, 10 (35%) patients had dizziness, and 14 (50%) had aural fullness. All patients met the inclusion criteria and did not complain of other symptoms. The right ear was involved in 16 (57%) patients and the left in 12 (43%). All patients had a normal otoscopic examination. All patients had normal symmetric hearing in the frequencies between 250 Hz to 8,000 Hz, except one patient with U-shaped symmetric high tone sensory neural hearing loss (40 dB at 4,000 Hz). Thirty-two patients were found to have asymmetric sensorineural hearing loss on EHF audiometry. Twenty-eight patients were found to have SSNHL on EHF audiology, while the other 4 did not meet the criteria of SSNHL, as one had a 30-dB difference in only one frequency, another had a 10-dB difference in 2 consecutive frequencies, one had 10-dB difference in 2 nonconsecutive frequencies, and the last had a 10-dB difference in only one frequency. The mean thresholds in the non-affected ear compared with the affected ear are shown on graph 1. The mean deltas between the sides were between 9.2 and 33 dB (worse in the affected ear). All patients were treated with an oral steroid (oral prednisone 1 mg/kg for 7 days).

## Discussion

In the past few decades, the measurement of the EHF audiometry range became possible due to the development of audiometers capable of delivering sounds with sufficient pressure levels, and earphones that can optimally transmit sound through the ear canal. Despite these advances, EHF audiometry is not routinely used in daily clinical practice. Various uses for EHF audiometry have been proposed, including the evaluation of EHF audiometry for early detection of ototoxicity<sup>2</sup> and as a more sensitive evaluation of noise-induced hearing loss,<sup>3</sup> though the latter indication is still controversial.<sup>4-6</sup> The effect of acoustic trauma on EHF thresholds was investigated in several studies demonstrating great variability of subjects,<sup>7,8</sup> though Borchgrevnik et al found EHF hearing loss at around 9000 Hz in these cases.<sup>9</sup> A few studies have also evaluated the auditory status of EHF in serous otitis media and recurrent acute otitis media, demonstrating elevated EHF thresholds as compared with the control group.<sup>10-13</sup> To the best of our knowledge, this is the largest series evaluating EHF hearing loss in patients presenting with acute tinnitus and intact audiometry results in frequencies of 250 to 8,000 Hz. In chronic tinnitus, no

pathology will be found in 7.4 to 20% of the patients using conventional audiometry.<sup>14</sup> Only a handful of studies have evaluated patients with chronic tinnitus with normal conventional pure tone audiometry utilizing EHF audiometry, with varying results.<sup>14-17</sup> However, in the present study, we evaluated patients with acute tinnitus. The major pathophysiological difference between acute tinnitus and chronic tinnitus is that chronic tinnitus results from pathological brain activity mainly in the temporal gyrus which presents the humans brain's hearing center. These reported central changes might be the cause of the persistent nature of chronic tinnitus. Changes in brain activity were reported in functional magnetic resonance imaging (MRI) and recently in PET CT demonstrating the central neural changes as a possible cause of chronic tinnitus. However, cochlear or peripheral neural pathology is to be suspected in acute tinnitus as central neural changes require time, and are thereby probably not the pathophysiological etiology of acute tinnitus. Acute tinnitus usually accompanies SSNHL that will be proven by a pathologic conventional hearing loss. Although the pathophysiology of SSNHL is not fully understood, several theories have been proposed including vascular occlusion, membrane breaks, and viral cochleitis or neuritis. The management of acute subjective tinnitus associated with SSNHL includes oral, intravenous, and/or intratympanic administration of corticosteroids as initial therapy.<sup>18</sup> Therapeutic strategies that improve hearing are reported to have positive effects on tinnitus in most patients with SSNHL together with tinnitus and recently also in patients with acute tinnitus with no pathology on audiometric tests.<sup>19</sup> The conjugated improvement in both hearing loss and tinnitus in those suffering from both signifies shared etiology; therefore, one should seek for hearing loss in patients presenting with tinnitus and normal conventional audiometry. As the latter encompasses the examination of 250 to 8,000 Hz only, it seems almost trivial and essential to evaluate hearing in the EHF up to 20000 Hz to demonstrate the "hidden" SSNHL. This is what was done in our study, proving that tinnitus alone is actually accompanied by EHF SSNHL. The downfalls of our study are its small size and lack of follow-up. However, according to our results, even patients presenting with acute tinnitus and no hearing loss sensation and with normal conventional hearing tests should be regarded as patients with SSNHL, as hearing impairment is observed on EHF audiometry. In view of our results, all patients presenting with acute tinnitus and a normal conventional audiometry should complete EHF audiometry up to 20,000 Hz and proceed to the sudden sensory hearing loss management protocol if EHF hearing loss is revealed. Further studies on larger cohorts should be designed to evaluate the effectiveness of SSNHL management protocols on the hereby newly reported EHF hearing loss in patients with acute tinnitus and normal conventional hearing tests.

## Conclusion

Extended high frequency audiometry up to 20,000 Hz should be completed in all patients presenting with acute tinnitus who have standard audiometry within the normal limits. If

hearing impairment is revealed, SSNHL management should be followed.

## Conflict of Interests

The authors have no conflict of interests to declare.

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