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Extended High-frequency Audiometry (9000---20 000 Hz). Usefulness in Audiological Diagnosis

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Abstract Early detection and appropriate treatment of hearing loss are essential to minimise the consequences of hearing loss. In addition to conventional audiometry (125---8000 Hz), extended high-frequency audiometry (9000---20 000 Hz) is available. This type of audiometry may be useful in early diagnosis of hearing loss in certain conditions, such as the ototoxic effect of cisplatin-based treatment, noise exposure or oral misunderstanding, especially in noisy environments. Eleven examples are shown in which extended high-frequency audiometry has been useful in early detection of hearing loss, despite the subject having a normal conventional audiometry. The goal of the present paper was to highlight the importance of the extended high-frequency audiometry examination for it to become a standard tool in routine audiological examinations.

KEYWORDS Extended high-frequency audiometry; Hearing loss; Tinnitus; Presbycusis; Cisplatin

Audiometría con extensión en altas frecuencias (9.000-20.000 Hz). Utilidad en el diagnóstico audiológico

Resumen La detección precoz y el tratamiento adecuado de la hipoacusia es fundamental para minimizar las consecuencias de la pérdida auditiva. Además de la audiometría convencional (125-8.000 Hz), disponemos de la audiometría con extensión en altas frecuencias (9.000-20.000 Hz), que puede ser de gran utilidad en el diagnóstico precoz de hipoacusia en ciertas patologías, como es el efecto ototóxico de los tratamientos quimioterápicos, la exposición a ruido o el mal entendimiento del lenguaje, especialmente en ambientes ruidosos. Aquí se presentan 11 casos clínicos en los que la audiometría con extensión en altas frecuencias ha ayudado en la detección precoz de la hipoacusia en diversas patologías, a pesar de tener una audiometría normal en frecuencias convencionales. Se pretende así destacar la importancia de la exploración audiométrica en altas frecuencias, con el fin de que se convierta en una herramienta habitual en la exploración audiológica

PALABRAS CLAVE Audiometría con extensión en altas frecuencias; Hipoacusia; Tinnitus; Presbiacusia; Cisplatino

Introduction Many factors are known to affect hearing, such as age, exposure to noise and taking potentially hearing-toxic drug. Both early detection of hearing loss and early intervention are essential to minimise hearing loss. Hearing is assessed through conventional tonal audiometry (125---8000 Hz). However, the human ear possesses an auditory range that reaches up to 20 000 Hz. Frequencies between 9000

and 20 000 Hz are called *extended high frequencies* (EHFs) in the international literature. Castilian Spanish has no defined equivalent term; such frequencies are called *high frequencies*, *ultra-high frequencies* or *extended high frequencies* by different authors, with the last term being the one that we are going to use to refer to them. The involvement of EHFs in auditory pathology is multiple. They can affect locating the sound¹ and understanding language, especially in noisy surroundings.^{2,3} They have also been linked with age-related hearing loss, ototoxicity and acoustic trauma. The ability to hear reduces bit by bit with age; this loss begins at the highest frequencies and progressively extends toward the lowest frequencies. The EHFs consequently become of special importance in age related hearing loss, as a method for early detection of such loss. An important role is played by EHF audiometry in monitoring the ototoxic effect of drugs such as cisplatin, which produces an initial hearing loss in the EHF range, later affecting conventional frequencies.⁴ However, the usefulness of EHF audiometry compared with conventional frequencies in early detection of acoustic trauma is still being debated.⁵⁻⁸ Reference hearing thresholds distributed by age groups have recently been published for both conventional frequencies⁹ and EAF.^{10,11} These values let us compare a subject's hearing with the standard for an ontologically normal population and establish the extent to which the subject's hearing departs from normality expressed as a percentile. We can thus evaluate patients being treated with chemotherapy or exposed to noise that report a hearing loss and for whom there is no prior audiometry available. The objective of this study was to emphasise the importance of EHF audiometry, to help to make it a normal tool in audiological examination. To do so, we present a series of clinical cases in which this type of audiometry has aided in early detection of various pathologies.

Methods**Subjects** The data for 11 subjects that consulted with suspicion of auditory pathology have been gathered. Each subject's audiometry at conventional frequencies was normal, and we performed an EHF audiometry on all the subjects (Table 1). The patients selected presented several pathologies that can cause hearing loss over the evolution of the disease.

Instrumental and Procedure All selected subjects received air conduction pure tone audiometry to determine the hearing threshold at different frequencies (125---20 000 Hz). The audiometric results obtained were compared with the previously, published normal Spanish population values at conventional frequencies⁹ and at EAFs.¹⁰ For the conventional frequency audiometry at conventional frequencies (125---8000 Hz), a Madsen Orbiter 922 clinical audiometer and supra-aural Telephonics TDH-39 ear-phones were used. The EHF audiometry (9000---20 000 Hz) was performed with the same audiometer and Koss HV/1A circumaural earphones. All the audiometric material was calibrated according to the manufacturers' recommendations as well as to ISO 389-1¹² and IEC 60645-1¹³ standards. The transducers were calibrated according to ISO 389-1¹² standards. The audiometry was performed manually by trained personnel, in agreement with ISO 8253-114 standards, with in a sound-proof booth. Auditory thresholds were determined based on the ascending method established in ISO 8253-114 standards. The thresholds at the conventional frequencies were calculated in decibels hearing level (dB HL) and the thresholds at EHFs, in dB sound pressure level (dB SPL).

Results Table 1 presents a summary of the characteristics of the subjects on which audiometry was performed using both conventional frequencies and EHFs. Cases 1, 2,

and 3 presented normal hearing levels up to 8000 Hz, with a drop to under the 95th percentile (P95) for their age group (20---29 years) at the frequencies from 9000 Hz (Fig. 1).

Case 4, who had been a musician in a rock group for 2 years, presented a hearing level lower than P95 only at the frequencies of 9000, 11 200 and 12 500 Hz (Fig. 1). The frequencies at which the subject departed most from the median were 12 000 and 16 000 Hz. Case 5 was a 26-year-old woman with sinonasal carcinoma, who had received treatment with radiotherapy and 3 cycles of cisplatin a year earlier. She presented a hearing level lower than P95 from 4000 Hz (Fig. 1). Case 6, who reported difficulties understanding in noisy surroundings, presented a hearing level very close to the median for his age group (30---39 years), with a drop to under P95 at frequencies from 14 000 Hz (Fig. 2). Cases 7, 8 and 9 presented hearing levels lower than P95 from 9000, 8000 and 4000 Hz, respectively (Fig. 2). Case 10 reported having tinnitus without hearing loss. Audiometry revealed a hearing level below P95 for the subject's age group (40---49 years) from 9000 Hz. Hearing at all the conventional frequencies was very close to the median for the age group (Fig. 3). Case 11, a 45-year-old man that had received treatment with cyclophosphamide, methotrexate and 5-fluorouracil, presented a hearing level under P95 from 9000 Hz. Audiometry in conventional frequencies was normal, although it was very close to P95 at 500 and 2000 Hz (Fig. 3).

Discussion Certain systemic pathologies can cause sensorineural hearing loss, which can be detected early by performing EHF audiometry. Fabry disease is a hereditary x-linked lysosomal storage disease. Within the clinical picture this disease produces is sensorineural hearing loss. In Case 1, the subjects showed no hearing loss, with normal audiometry at conventional frequencies, which could lead us to believe that this subject presented no hearing compromise. However, when EHF audiometry was performed, an important loss at all the frequencies between 9000 and 20 000 Hz was seen. Many patients come to consultation for tinnitus, without reporting hearing loss, as Cases 2 and 10 did. In Case 2, the subject reported tinnitus and dizziness after using minoxidil. Audiometry at conventional frequencies was normal; however, the EHF audiometry revealed that the hearing thresholds were much below normal, a loss that could explain the tinnitus. Radiotherapy in the head area is another cause of sensorineural hearing loss. In Case 3, a patient treated with radiotherapy due to a nasopharyngeal carcinoma, presented a hearing loss that was only detectable in the EHF audiometry, especially at the frequencies between 9000 and 16 000 Hz.

Case 4 was a subject exposed to very loud music. A hearing loss could be seen in EHF audiometry, especially at the frequencies located between 11 200 and 14 000 Hz, departing further from the median at 12 000 and 16 000 Hz. Some authors have found that acoustic trauma affects the frequencies of 3000---6000 Hz and that it also affects EAF considerably, 5 especially at 14 000 Hz 6 and 16 000 Hz. 7 EHF audiometry is more sensitive than conventional audiometry, particularly in young subjects, 7 although not all authors believe that EHF audiometry provides additional information. 8

Consequently, we still do not have conclusive data to establish the usefulness of EHF audiometry in early detection of noise-induced hearing loss. The usefulness of EHF audiometry is well known in early detection of hearing loss in subjects submitted to platinum-derived chemotherapy treatments, with cisplatin being the drug that presents the greatest risk of developing ototoxic effects. Other chemotherapy drugs such as methotrexate and cyclophosphamide are also known to cause sensorineural hearing loss. In Case 5, the patient was treated with cisplatin and, in the audiometry, a severe hearing loss was revealed, even detectable at the conventional frequencies (4000 Hz). It is important to point out that, although the hearing threshold was extremely reduced, hearing was maintained at all the frequencies up to 20 000 Hz. This is

something that occurs in younger subjects, who preserve their hearing up to very high frequencies, even though their hearing is lower than normal (Fig. 1). In Case 11, the compromise in hearing could only be seen when the audiometry was performed at EHF. The frequencies included between 500 and 4000 Hz have traditionally been considered to be the most important for understanding speech. The range of conversational frequencies of the human voice lies between 250 and 3000 Hz; however, it is true that some phonemes are located between 4000 and 8000 Hz, or even at higher frequencies, especially in fricative consonants.³ Understanding speech poor lyin noisy environments, as occurred in Case 6, could be explained by the hearing loss at the higher frequencies (in this case, at the frequencies above 14 000 Hz). Many cases with suspicion of deafness arising from genetic or autoimmune origin can benefit from performing an EHF audiometric test for early detection of the hearing loss. In Cases 7, 8 and 9, this loss of hearing was revealed at the EHF, with greater or lesser compromise of the highest conventional frequencies. For all these reasons, EHF audiometry can be extremely useful in early detection of sensorineural hearing loss. Performance of EHF audiometry should consequently be established in normal clinical practice to expand the study of patient hearing ranges.

Conflict of Interests The authors have no conflicts of interest to declare.

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Tabla 1

Case	Age	Sex	Pathology
1	24	M	Fabry disease
2	26	M	Tinnitus following minoxidil
3	20	F	Nasopharyngeal Ca treated with RT
4	21	M	Rock musician
5	26	M	Sinonasal Ca treated with RT+cisplatin
6	39	M	Lack of understanding in noisy surroundings
7	38	M	Suspicion of genetic hearing loss
8	33	M	Fluctuating hearing loss
9	39	F	Suspicion of autoimmune hearing loss
10	49	M	Tinnitus
11	45	F	Treatment with cyclophosphamide+MTX+5-FU

Ca: carcinoma; FU: fluorouracil; M: male; F: female; MTX: methotrexate; RT: radiotherapy.

Figura 1

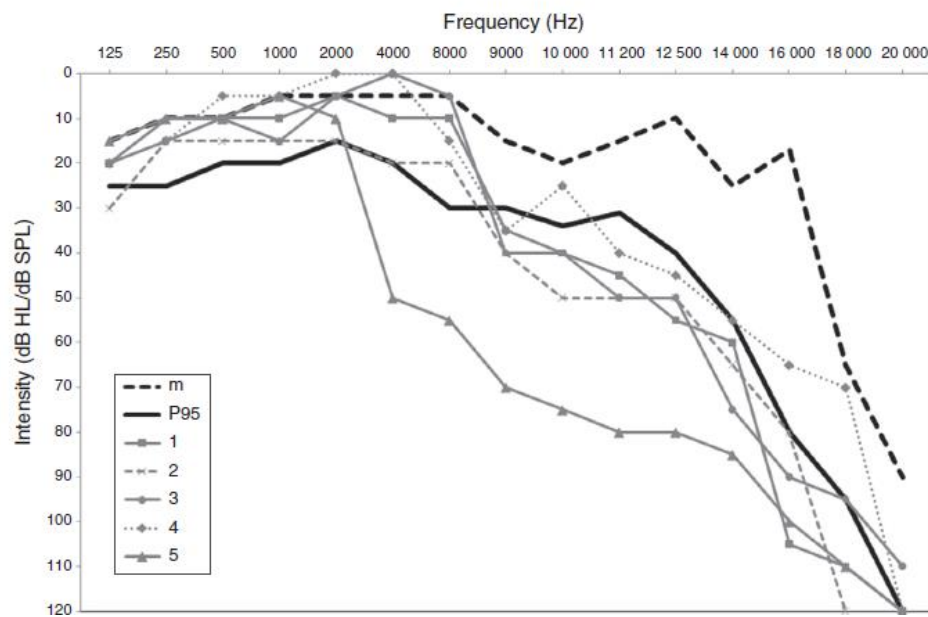


Figura 2

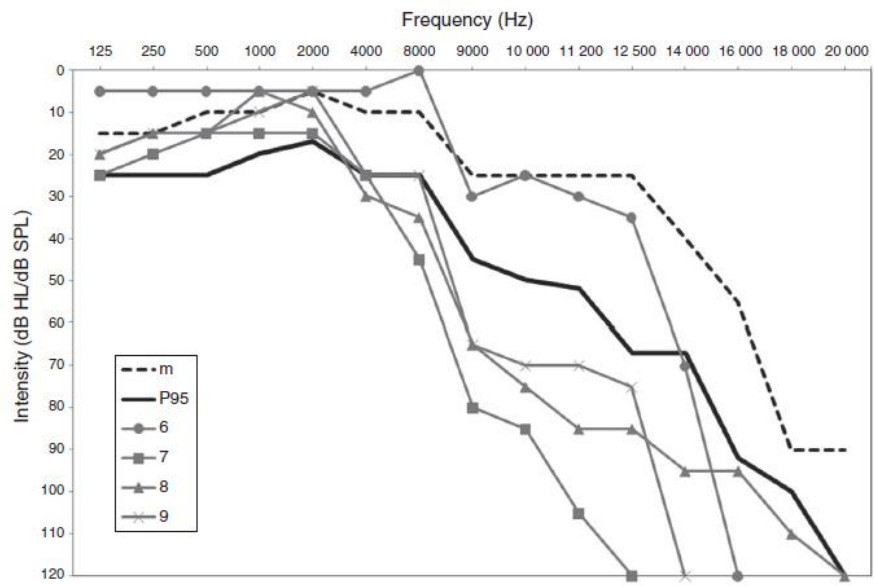


Figura 3

