ORIGINAL ARTICLE

Malformation of the Eighth Cranial Nerve in Children

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Cochlear nerve; Inner ear; Cochlear implant; Hearing loss

Abstract

Introduction and objectives: Prevalence of congenital sensorineural hearing loss (SNHL) is approximately 1.5–6 in every 1000 newborns. Dysfunction of the auditory nerve (auditory neuropathy) may be involved in up to 1%–10% of cases; hearing losses because of vestibulocochlear nerve (VCN) aplasia are less frequent.

The objectives of this study were to describe clinical manifestations, hearing thresholds and aetiology of children with SNHL and VCN aplasia.

Methodology: We present 34 children (mean age 20 months) with auditory nerve malformation and profound HL taken from a sample of 385 children implanted in a 10-year period. We studied demographic characteristics, hearing, genetics, risk factors and associated malformations (Casselman’s and Sennaroglu’s classifications). Data were processed using a bivariate descriptive statistical analysis (P<.05).

Results: Of all the cases, 58.8% were bilateral (Iia/Ila and I/I were the most common). Of the unilateral cases, Ilb was the most frequent. Auditory screening showed a sensitivity of 77.4%.

A relationship among bilateral cases and systemic pathology was observed. We found a statistically significant difference when comparing hearing loss impairment and patients with different types of aplasia as defined by Casselman’s classification. Computed tomography (CT) scan yielded a sensitivity of 46.3% and a specificity of 85.7%. However, magnetic resonance imaging (MRI) was the most sensitive imaging test.

Conclusions: Ten percent of the children in a cochlear implant study had aplasia or hypoplasia of the auditory nerve. The degree of auditory loss was directly related to the different types of aplasia (Casselman’s classification) Although CT scan and MRI are complementary, the MRI is the test of choice for detecting auditory nerve malformation.

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Malformaciones del octavo par en niños

Resumen

Introducción y objetivos: La prevalencia de la hipoacusia neurosensorial (HNS) congénita es aproximadamente de 1,5-6 de cada 1.000 nacimientos. La disfunción del nervio auditivo (neuropatía auditiva) puede estar presente hasta en el 1-10% de los casos de HNS en niños, siendo menos frecuentes aquellas pérdidas debidas a una aplasia o hipoplasia del nervio auditivo. Los objetivos del estudio son describir la clínica, umbrales auditivos y etiología en una muestra de niños con HNS y aplasia o hipoplasia del octavo par.

Metodología: Presentamos 34 niños (edad media 20 meses) con malformación del nervio auditivo e HNS profunda de una muestra de 385 niños implantados en los últimos 10 años. Estudiamos las características demográficas, clínicas y malformaciones asociadas (clasificación de Casselman y Sennaroglu). Los datos fueron procesados usando un análisis estadístico descriptivo bivariante (p<0.05).

Resultados: Un 58,8% fueron bilaterales (ii/ia/ia y si fueron los más frecuentes). De los unilaterales el ib fue el más frecuente. La sensibilidad del cribado auditivo fue de un 77,4%. Encontramos diferencias estadísticamente significativas entre el grado de hipoacusia y los distintos tipos de aplasia (clasificación de Casselman).

La sensibilidad de la TC fue del 46,3% y la especificidad del 85,7%. La RNM fue la prueba de imagen más sensible.

Conclusiones: Un 10% de los niños en estudio para un implante coclear tienen una aplasia o hipoplasia del nervio auditivo. El grado de pérdida auditiva está directamente relacionado con los distintos tipos de aplasia (clasificación de Casselman). Aunque la TC y la RNM son complementarias, la RNM es el test de elección para la detección de malformaciones del nervio auditivo.

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Introduction

Congenital sensoneural hearing loss (SNHL) is one of the most common problems in newborns, affecting between 1.5 and 6 children out of every 1000 living newborns. Although the cause of the problem may be located anywhere in the auditory pathway, it is well known that the most common site is the cochlear, whether this be due to congenital or acquired causes, and in particular at sensory hair cell level. Recent studies suggest that the dysfunction of the auditory nerve (auditory neuropathy) may be involved in 1%-10% of cases of SNHL in children, with auditory losses resulting from anatomical changes to the nerve (aplasias and hypoplasias) being less frequent.

In our experience 10% of children in a cochlear pre-implant study will present with an aplasia or hypoplasia of the auditory nerve and this finding has increased over time due to improvements in magnetic resonance imaging. However, and as we will describe below, radiologic findings regarding aplasia of the auditory nerve are not 100% proof of a total absence of auditory function.

Material and Methods

The sample included 34 children patients (mean age: 20.5±27.0 months) who had been diagnosed with SNHL due to aplasia or hypoplasia of the auditory nerve with or without associated vestibulocochlear nerve malformations. We based our diagnosis and study primarily on the MRI imaging findings in accordance with the techniques described by Casselman¹: (T2) 3 Teslas MRI: slices of 0.4–0.7 mm perpendicular to the pathway of the facial nerve and of the eighth cranial nerve in the internal auditory canal and at the cerebellopontine angle level (parasagittal reconstruction) and volume reconstruction in the axial plane (three-dimensional Fourier transformation-constructive interference in steady state [3DFT-CISS]), and at the same time a routine axial T2 weighted brain imaging study to rule out central nervous system pathologies. The imaging study was completed with high-resolution CT of the temporal bone (axial plane performed in slices parallel to the infraorbital line up to 0.3 mm thick. A 512×512 matrix was used and the images of each ear were separated with a field of vision of approximately 9 cm).

Hearing tests included: tone and/or speech audiology (Affinity 2.0/Equinox 2.0), tympanometry (Impedance AZ 26 Audiometer), otoacoustic emissions (Madsen Accuscreen) and brainstem auditory and steady state evoked potentials (Navigator Pro Biologic: PEA and MASTER II).

Malformations of the auditory and vestibulocochlear nerves were grouped according to the Casselman¹ (Figs. 1–5) and Sennaroglu² classifications respectively. All data were processed using bivariate statistical analysis (P<.05).
Malformation of the Eighth Cranial Nerve in Children

Results

Epidemiological

In 41.2% of patients auditory nerve lesions were unilateral and in 58.8% they were bilateral. Type Iib was the most common of the unilateral lesions and the combinations Ila/Ila and I/I were the most common bilateral lesion types. Unilateral patients were predominantly male (11 cases out of 14), compared with the bilateral cases who were mainly female (11 cases out of 20).

The majority of our patients were referred to us after screening hearing programmes (44.1%) or suspected impairment by the parents (26.5%). Only 20.5% (7 patients) presented with family histories of hearing impairment and only (patient Iib/Iib) presented with a genetic study which tested positive for hearing impairment (gene GJB2).

Regarding other known hearing impairment factors, 55.9% (19 cases out of 34) presented with an associated

Figure 1 (1 and 2 CT; 3 MRI). Casselman type I bilateral. Child of 2 years of age with profound bilateral sensoneural hearing loss, bilateral stenosis of both internal auditory canals and absence of the eighth bilateral cranial nerve. A neutral structure in the inner auditory canal was only observed in the sagittal projection (3.1) with preservation of the facial nerve function. Cochlear nerves were preserved and there was dysplasia of the semicircular canals (1.1).

Figure 2 (1 and 4 CT; 2 and 3 MRI). Casselman type IIa right unilateral. Stenosis of the right inner auditory canal with an absence of cochlear nerve. (1.1) The left side is wider and there is a cochlear branch in the expected site. Right vestibular dysplasia (*). No right vestibulocochlear nerve at cerebellopontine angle level (2.1) posterior to the facial nerve of similar size. Trapped right cochlear nerve. Compare with bony canal of the cochlear nerve on left side (circles).
factor. In a third (32.4%) we found syndromic type changes (5 patients presented with a brachial-ENT-renal syndrome). The majority of our patients (26 cases out of 34) had no alteration to other cranial nerves.

We also observed that in those patients with normal cochlear and vestibular nerves the lack of risk factors was more pronounced ($P=0.029$).

Malformations of the auricle were more common in the bilateral cases (35%) than in the unilateral cases (7.1%), of borderline statistical significance ($P=0.067$).

**Audiological Examinations**

Auditory screening yielded 77.4% sensitivity for the bilateral cases. Otoemissions were positive in 10 ears (10/68), all without associated vestibulocochlear malformations (5 with normal nerve, 2 with type I and 3 with type IIb).

Regarding brainstem evoked response audiometry (BERA) we observed that the types I presented with a higher degree of hearing loss than the others (thresholds ≥120 dB). Profound SNHL predominated in types Ila and IIb, but there
Figure 5  Casselman classification. Source: Casselman.4

Figure 6  Degree of hearing loss according to the Casselman classification.

was an increase in the severe and moderate to severe cases (thresholds below 120 dB in 50% of cases). Type III had the best audiological results, possibly due to isolated agensis of the vestibular nerve and to being able to present a normal vestibulocochlear status. These differences were statistically significant with regards to the patients without aplasia or hypoplasia of the auditory nerve (P<.05).

Steady state evoked potentials (SSEP) were carried out on all of our patients, observing similar thresholds to the conventional BERA and statistically significant differences established as P<.001 between the 5 groups (Casselman normal nerve and types I, IIa, IIb and III) and in any frequency detected by the SSEP (Fig. 6).

For those children whose age was sufficient to carry out a tone audiometry (n=18) we observed a statistically significant difference (P<.01) between the ears without aplasia or hypoplasia of the vestibulocochlear nerve and for any type of Casselman classification. This confirms that types I are audiological the poorest, and this progressively improves in types IIa, IIb and III. At the same time we carried out a frequency study to see if any of them was more highly affected than the rest. We saw how in type I all the frequencies were equally affected (250, 500, 1000, 2000, and 4000 Hz), but we found statistically significant differences (P<.001) in type III, where the 1000 Hz frequency was the most compromised compared with the 250, 500, and 2000 Hz and in IIb, where the 1000, 2000, and 4000 Hz frequencies were the poorest compared with the 250 and 500 Hz ones. Regarding subgroup III, no statistically significant differences were detected, but there was as major tendency towards frequency alteration in 250, 500, and 1000 compared with 2000 and 4000 Hz.

Imaging Tests

MRI was confirmed as the most sensitive test to view malformations of the auditory nerve, with the most commonly diagnosed ones being aplasia (42.6%) and hypoplasia (29.4%) of the cochlear nerve, followed by aplasia of the upper vestibular nerve (23.5%) and the lower vestibular nerve (22.1%), which implies that when there is a neutral deficit in the MRI, the nerve most frequently involved will be the cochlear nerve.

Of the 68 ears examined (54 with some type of aplasia or hypoplasia of the auditory nerve), the CT findings led to suspected aplasia or hypoplasia depending on the diameter of the internal auditory canal (IAC) ≤ 3 mm in 25 of them, which indicated a sensitivity of 46.3%; however, of the 14 normal ears according to the MRI study, in 12 of them there was no suspected aplasia or hypoplasia of the nerve from the CT scan (specificity: 85.7%) (Fig. 7).

When we compare vestibulocochlear changes to auditory nerve malformations, we observe that there is a relationship between type 2 incomplete partition and the Casselman type IIa (P<.001) and the presence of vestibular hypoplasia in 80% of types III (P<.001).

An enlarged vestibular aqueduct was observed in 7 ears (10.3%), with a significantly superior relationship found in type I (33.3%) compared with the other malformations of the auditory nerve. The relationship between an enlarged vestibular aqueduct and type 2 incomplete partition described by Sennaroglu2 was observed in 13% of the patients (2 out of 15). Three ears (4.4%) presented with enlarged cochlear aqueduct (2 type Ia and 1 type I).

When both imaging tests (CT and MRI) were compared we observed that when the IAC diameter was reduced in the CT (≤ 3 mm), the nerve frequency affected was the cochlear nerve (P=.006), followed by the superior vestibular nerve (P=.040) and the inferior vestibular nerve (P=.093) (Fig. 8).
we found just 3 (8.82%) patients with auditory neuropathy criteria.

Statistically significant differences were observed between the different frequencies in ia, ib and ii, and also statistically significant outcomes between the degree of hearing loss and the different types of Casselman classifications, since from type i to type iii the relative frequency of profound hearing loss progressively diminishes (Fig. 6). This would be explained by the improved neural and structural preservation of the inner ear as we advance in the Casselman classification.

The relationship between aplasias and hypoaplasias of the auditory nerve and vestibulocochlear malformations has already been described by other authors, with the appearance of malformations with neural involvement accounting for up to 84%. It is also true that the cochlear nerve may be absent despite there being a normal cochlear nerve in up to 40% of cases, and that the development of the sensory hair may occur in absence of innervation. We believe that embryologically the development of the bony labyrinth takes place between the fourth and eighth week of pregnancy and that inner ear malformations which are detectable through imaging may be due to systemic problems in general during this period. These factors will lead to both a structural change in the inner ear and to changes in the actual sensory hairs cells on whose neurotrophic factors the development of the spiral ganglion cells and the actual innervation of the inner ear will depend. This leads us to consider that a deficit of the neurotrophic factor generated by the sensory hair cell will produce a morphological deficit in the auditory nerve with IAC diameter which will be progressively greater the more advanced in pregnancy said deficit occurs. This suggests that those ears with normal IAC and auditory nerve impairment will be due to a change which occurred after week 24 of pregnancy (when IAC development terminates) and those with a reduced diameter will be due to an impairment prior to this date.

The positive predictive value (PPV) of CT is extremely high (92%; 23 out of 25), unlike the genuinely poor negative predictive value which is approximately 27.9% (12 out of 43). As with MRI testing, CT imaging tests are evolving and the current measurement under 1.4 mm of the cochlear nerve canal as it enters the cochlear has proven to be highly predictive in diagnosis of neural involvement.

Discussion

We wish to highlight that in our series genetic load was of little influence (one positive GJB2 case) and also that extrinsic factors were of great influence in the alteration of embryonic development of the auditory nerve and/or inner ear. We also observed that when the impairment was unilateral, there was less probability of any associated pathology (P=.08), unlike the bilateral cases, possibly due to the fact that a systemic change will lead to an impairment in the organogenesis of the inner ear.

In our study we found there were differences regarding gender, especially in the unilateral cases, where females predominated (78.6%); however, other authors observed no differences.

We found it striking that in type ii a patients according to Casselman there was no association with impairment of other cranial nerves, unlike the rest of the patients where the incidence was 29.2%. This suggests that there is a marked tendency (P=.078) for types ii not to be associated with impairment in other cranial nerves. This is probably due to the fact that the organogenesis of the cochlear nerve is separate from the other cranial nerves.

Neonatal screening with transient evoked otoacoustic emissions (TOAEs) showed low sensitivity (77.4%). This is the result of those patients classified by Casselman as ili, who presented with normal cochlear and vestibular nerves and aplasia or hypoplasia of auditory nerve, and whose conditions were not initially detected.

Several authors believe that hypoplasia of the auditory nerve in the majority of cases is a form of auditory neuropathy, because they have found in their series up to 70% of patients with aplasia and hypoplasia of the auditory nerve and with electrophysiological characteristics of auditory neuropathy. The Sydney Cochlear Implant Centre (SCIC) presented a series of 80 children with auditory neuropathy where the majority obtained favourable outcomes with cochlear implants. This suggests that 75% of neuropathies is due to a change in the function of the inner sensory hair, whilst all other cases stem from a change in the synapses, auditory nerve, cochlear nucleus or central auditory pathway. Other authors report 36% of neuropathies among cases of cochlear nerve hypoplasia. In our casuistry...
In accordance with previous data, we believe that when a patient has profound SNHL the imaging technique of choice is MRI with imaging studies of the bony labyrinth and the auditory nerve. We consider the CT to be an essential complementary test for marking the bony component of the otic capsule and the cochlear canal and as a previous step to surgery.

Conclusions

We observed that there was an association between the degree of hearing loss and the different types of auditory nerve malformation (according to Casselman classification). Type I patients present with the poorest hearing and there is progressively better hearing up to type III.

MRI is the imaging test of choice for the detection of auditory nerve malfunctions, with the most frequent diagnoses being aplasia (42.6%) and hypoplasia (29.4%) of the cochlear nerve. Specificity of CT scans in the diagnosis of auditory nerve malformations is high (85.7%), but sensitivity is poor (56.3%).

Conflict of Interests

The authors have no conflict of interests to declare.

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