International Journal of Pediatric Otorhinolaryngology 78 (2014) 268–271

Contents lists available at ScienceDirect

International Journal of Pediatric Otorhinolaryngology

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

Computed tomography demonstrates abnormalities of contralateral ear in subjects with unilateral sensorineural hearing loss☆

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ARTICLE INFO

Article history:
Received 12 September 2013
Received in revised form 15 November 2013
Accepted 17 November 2013
Available online 25 November 2013

Keywords:
Temporal bone anatomy
Unilateral sensorineural hearing loss
Pediatric hearing loss
Inner ear abnormalities
Bony island lucency
Temporal bone computed tomography

ABSTRACT

Purpose: Prior studies have associated gross inner ear abnormalities with pediatric sensorineural hearing loss (SNHL) using computed tomography (CT). No studies to date have specifically investigated morphologic inner ear abnormalities involving the contralateral unaffected ear in patients with unilateral SNHL. The purpose of this study is to evaluate contralateral inner ear structures of subjects with unilateral SNHL but no grossly abnormal findings on CT.

Materials and methods: IRB-approved retrospective analysis of pediatric temporal bone CT scans. 97 temporal bone CT scans, previously interpreted as "normal" based upon previously accepted guidelines by board certified neuroradiologists, were assessed using 12 measurements of the semicircular canals, cochlea and vestibule. The control-group consisted of 72 "normal" temporal bone CTs with underlying SNHL in the subject excluded. The study-group consisted of 25 normal-hearing contralateral temporal bones in subjects with unilateral SNHL. Multivariate analysis of covariance (MANCOVA) was then conducted to evaluate for differences between the study and control group.

Results: Cochlea basal turn lumen width was significantly greater in magnitude and central lucency of the lateral semicircular canal bony island was significantly lower in density for audiometrically normal ears of subjects with unilateral SNHL compared to controls.

Conclusion: Abnormalities of the inner ear were present in the contralateral audiometrically normal ears of subjects with unilateral SNHL. These data suggest that patients with unilateral SNHL may have a more pervasive disease process that results in abnormalities of both ears. The findings of a cochlea basal turn lumen width disparity >5% from "normal" and/or a lateral semicircular canal bony island central lucency disparity of >5% from "normal" may indicate inherent risk to the contralateral unaffected ear in pediatric patients with unilateral sensorineural hearing loss.

1. Introduction

Computed tomography (CT) of the temporal bone has proven to be an invaluable diagnostic tool in the evaluation of children with unilateral sensorineural hearing loss (USNHL) [1], providing insight into etiology and impacting both the prognosis and management of those children affected [2]. Prior studies have shown that as many as 35% of patients with USNHL demonstrated inner ear malformations evident on CT within the affected ear [3], and as imaging quality continues to improve, previously unrecognized abnormalities are increasingly detected.

Less attention has been paid to the contralateral ear in patients with USNHL, yet there is evidence that patients with USNHL may have inner ear abnormalities within their normal hearing ear as well. This has been described in cases of bilateral EVA in which only one ear demonstrated hearing impairment at the time of imaging [4]. These findings have important implications, as USNHL may represent an early manifestation of bilateral disease in certain

☆ This original work was presented at the podium at the American Society for Pediatric Otolaryngology (ASPO) meeting in Washington, DC/Arlington, VA in April, 2013.

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http://dx.doi.org/10.1016/j.ijporl.2013.11.020

patients. In our study, we evaluate the contralateral ear in children with idiopathic USNHL using temporal bone CT.

2. Materials and methods

2.1. Subjects

This HIPAA-compliant IRB-approved retrospective study analyzed temporal bone CT scans of children aged 0–18 years who underwent evaluation for hearing loss at a tertiary care medical center from 2006 to 2012. The study group consisted of 25 children (12 females and 13 males) diagnosed with USNHL with no audiometric abnormality in the contralateral ear, and CT scans of these ears interpreted as "normal" by board-certified neuroradiologists. We excluded all children with a diagnosis of USNHL attributed to: conductive hearing loss; auditory neuropathy; SNHL due to recurrent otitis media, meningitis, maternal cytomegalovirus infection, rubella, toxoplasmosis, aminoglycoside exposure, ECMO, intraventricular hemorrhage, an autoimmune process or a syndromic disease. Patients ranged in age from 4 months to 17 years (average = 8 years).

The control group consisted of 72 ears in pediatric subjects who underwent evaluation with temporal bone CT scanning, i.e. for conductive hearing loss. All subjects had audiograms that were reviewed by a certified clinical audiologist to rule out underlying SNHL. 38 subjects were included: 18 females (36 ears) and 20 males (36 ears). Four of the subject ears were excluded from the study due to inner ear erosion from cholesteatoma or mixed hearing loss. Patients ranged in age from 2 to 18 years old (average = 10 years).

2.2. Measurements

Measurements of semicircular canals, cochlea and vestibule were made on temporal bone CT scans as previously described [5]. These measurements were chosen as they have demonstrated utility in identifying subtle inner ear abnormalities in prior studies [2,6–10].

2.3. Computed tomography of the temporal bone analysis

All temporal bone studies were non-contrast enhanced studies performed using standard technique on GE® 64-slice scanners with slice-thickness of 0.625 mm. The studies were acquired in the axial plane with coronal images reformatted from the axial data. Images were acquired with a focused field of view ranging from 20 to 24 cm and with a high-resolution bone algorithm and reviewed on Phillips PACS (picture archiving and communications systems) terminals by one radiologist. Inter-rater reliability was established by random sampling review by two other neuroradiologists.

Table 1
Demographic composition of the subject group compared to the study group.

Demographic	Subjects	Controls
Mean age (years) [range]	8 [0.3–17]	10 [2–18]
Sex (# of ears included)	25	72
Male	13 (52%)	36 (50%)
Female	12 (48%)	36 (50%)
Race (# of ears included)	25	72
Asian	0	2 (2.7%)
African-American	5 (20%)	2 (2.7%)
Burmese	0	2 (2.7%)
Caucasian	12 (48%)	56 (77.7%)
Hispanic	7 (28%)	7 (9.7%)
Unknown	1 (4%)	1 (1.4%)
Other	–	2 (2.7%)

2.4. Statistics

A one-way between group multivariate analysis of covariance (MANCOVA) was performed for each dependent measure of the inner ear, with group as the independent variable (group 1: audiometrically normal ears of subjects with USNHL; group 2: sensorineural hearing loss excluded controls) and sex (male, female) as a covariate. Sex was previously determined to be a significant covariate [5]. All statistical analyses were performed with statistical software (SPSS, version 16.0; SPSS, Chicago, Ill).

3. Results

A total of 97 ears were assessed: 25 normal-hearing contralateral ears in subjects with unilateral sensorineural hearing loss and 72 control ears in subjects with no history of sensorineural hearing loss. The mean age at study, the sex and the race demographics are recorded in Table 1.

MANCOVA, controlling for sex, revealed statistically significant differences between inner ear measurements from audiometrically normal ears of subjects with USNHL compared to controls, as follows (as designated with an * in Table 2, with full measurement details):

(1) Cochlea basal turn lumen width was 6.54% wider in the SNHL study group (mean ± SD; 1.91 ± .29) compared to controls (mean ± SD; 1.78 ± .21) [$F(1,94) = 5.372$, $p = .023$].

Table 2
Summary of temporal bone anatomical measurements in the normal-hearing ear of subjects with contralateral unilateral sensorineural hearing loss compared to subjects without sensorineural hearing loss. Statistical significance was identified for the cochlear basal turn lumen width and the central lucency of the bony island of the lateral semicircular canal, both highlighted with the asterisk (*).

Measurement parameter	Subject ear			Control ear		
	Mean	SD	Range	Mean	SD	Range
LSCC bony island width (mm)	3.94	0.64	2.9–5.2	4.12	0.46	3.0–5.9
SSCC bony island width (mm)	5.43	0.64	4.5–6.7	5.32	0.49	4.5–6.4
Cochlear height (mm)	4.64	0.42	4.0–5.9	4.49	0.38	3.5–5.6
Cochlear length (mm)	5.88	0.32	5.4–6.4	5.91	0.38	5.1–6.7
Cochlear basal turn lumen width* (mm)	1.91	0.29	1.2–2.5	1.78	0.21	1.2–2.3
Bony canal [aperture] for the cochlear nerve width (mm)	2.38	0.27	1.8–2.9	2.42	0.43	1.4–3.6
Bony canal [aperture] for the cochlear nerve height (mm)	1.16	0.25	0.7–1.6	1.11	0.21	0.7–1.7
Vestibular width (mm)	3.18	0.22	2.7–3.6	3.09	0.27	2.4–3.5
Vestibular length (mm)	6.16	0.51	5.2–7	5.98	0.38	5.1–7
Central lucency of the bony island of the LSCC* (HU)	1716	182	1009–2023	1805	106	1577–2019
Cochlear height [coronal] (mm)	5.09	0.47	3.9–5.8	5.09	0.60	3.4–6
Vestibule oblique diameter (mm)	5.41	0.48	4.4–6.1	5.43	0.39	4.4–6.3