J Hear Sci, 2018; 8(4): 29–33
DOI: 10.17430/1003182

AUDITORY PROCESSING IN CHILDREN WITH CHRONIC SUPPURATIVE OTITIS MEDIA

Contributions:
A Study design/planning
B Data collection/entry
C Data analysis/statistics
D Data interpretation
E Preparation of manuscript
F Literature analysis/search
G Funds collection

Augustina Noel[BEF], Arun Alexander[ACDE], Anuprasad Sreenivasan[ACDE], Saravanan Palani[ACE]

Department of Otolaryngology, Jawaharlal Institute of Postgraduate Medical Education and Research, Pondicherry 605006, India

Corresponding author: Anuprasad Sreenivasan, Department of Otolaryngology, JIPMER, Pondicherry 605006, India. Email: anuprasadss@gmail.com

Summary

Background: Chronic suppurative otitis media (CSOM) in early childhood can lead to auditory processing disorders in later life even though the hearing sensitivity has returned to normal. There is a dearth of studies in the literature that have evaluated the auditory processing in children with later onset of CSOM.

Material and methods: Auditory processing was measured in terms of frequency discrimination (difference limen frequency, DLF), intensity discrimination (difference limen intensity, DLI), and gap detection threshold (GDT) in 15 children with CSOM of mean age 13 years as well as in 15 normal hearing children of comparable age.

Results: An independent *t*-test was used to gauge the significance between the groups for all three parameters. There was a statistically significant difference ($p < 0.05$) for all three.

Conclusion: The results confirm that conductive hearing loss impairs the auditory processing abilities of children with CSOM, even in those aged 9 to 15 years. These findings highlight the importance of early intervention in cases of CSOM.

Key words: Auditory processing • chronic suppurative otitis media • frequency discrimination • intensity discrimination • gap detection

PROCESAMIENTO AUDITIVO EN NIÑOS CON OTITIS MEDIA SUPURATIVA CRÓNICA

Resumen

Antecedentes: la otitis media supurativa crónica (CSOM, por sus siglas en inglés) en la temprana infancia puede llevar a trastornos del procesamiento auditivo en la vida posterior, aunque la sensibilidad auditiva haya vuelto a la normalidad. Hay una escasez de estudios en la literatura que hayan evaluado el procesamiento auditivo en niños con un inicio tardío de CSOM.

Material y métodos: el procesamiento auditivo se midió en términos de discriminación de frecuencia (diferenciación del umbral de frecuencias, DLF), discriminación de intensidad (diferencia del umbral de intensidad, DLI) y umbral de detección de brecha (GDT) en 15 niños con CSOM de edad promedio de 13 años así como, también. en 15 niños con audición normal de edad comparable.

Resultados: se usó t-test para variables independiente para medir el grado de significación entre los grupos para las tres variables. Hubo una diferencia estadísticamente significativa (p <0.05) para los tres.

Conclusión: los resultados confirman que la pérdida conductiva de audición afecta la capacidad de procesamiento auditivo de los niños con CSOM, incluso para los niños de 9 a 15 años. Estos hallazgos resaltan la importancia de la intervención temprana en casos de CSOM.

Palabras clave: procesamiento auditivo • otitis media supurativa crónica • discriminación de frecuencia • discriminación de intensidad • detección de brechas.

ОБРАБОТКА СЛУХОВОЙ ИНФОРМАЦИИ У ДЕТЕЙ С ХРОНИЧЕСКИМ ГНОЙНЫМ СРЕДНИМ ОТИТОМ

Аннотация

Вступление: хронический гнойный средний отит (CSOM) в раннем возрасте может привести к нарушениям обработки слуховой информациив дальнейшей жизни, даже если восприятие звука вернулось в нормальное состояние. В литературе нет исследований, которые бы оценивали обработку слуховой информации детьми, у которых позднее развился CSOM.

Материалы и методы: Обработка слуховой информации была измерена методами определения дифференциальных порогов различения частоты (difference limen frequency, DLF) и интенсивности (difference limen intensity, DLI) и при помощи теста обнаружения паузы (gap detection threshold, GDT) у 15 детей с хроническим гнойным воспалением среднего уха в возрасте 13 лет, а также у 15 детей с нормальным слухом в таком же возрасте.

Результаты: Для оценки значимости различия между группами для всех трех параметров был использован независимый t-критерий Стьюдента. Возникла статистически значимая разница (p<0,05) для всех трех параметров.

Выводы: Результаты подтверждают, что кондуктивная тугоухость негативно влияет на способность обработки звуковой информации у детей с хроническим гнойным воспалением среднего уха, даже у детей в возрасте от 9 до 15 лет. Эти результаты указывают на важность раннего лечения в случаях хронического гнойного воспаления среднего уха.

Ключевые слова: обработка звука • хроническое гнойное воспаление среднего уха • различение частоты • различение интенсивности • обнаружение паузы.

PRZETWARZANIE SŁUCHOWE U DZIECI Z PRZEWLEKŁYM ROPNYM ZAPALENIEM UCHA ŚRODKOWEGO

Streszczenie

Wstęp: Przewlekłe ropne zapalenie ucha środkowego (CSOM) we wczesnym dzieciństwie może prowadzić do zaburzeń przetwarzania słuchowego w późniejszym życiu, nawet jeśli wrażliwość słuchowa wróciła do normy. W literaturze brak jest badań oceniających przetwarzanie słuchowe u dzieci, u których później wystąpiło CSOM.

Materiał i metody: Przetwarzanie słuchowe mierzono w zakresie dyskryminacji częstotliwościowej (*difference limen frequency*, DLF), dyskryminacji intensywności (*difference limen intensity*, DLI) i progu wykrywania przerwy (*gap detection threshold*, GDT) u 15 dzieci z CSOM w średnim wieku 13 lat, oraz u 15 dzieci z prawidłowym słuchem w porównywalnym wieku.

Wyniki: Do oszacowania istotności różnicy między grupami dla wszystkich trzech parametrów użyto niezależnego testu t-Studenta. Wystąpiła statystycznie istotna różnica (p <0,05) dla wszystkich trzech parametrów.

Wnioski: Wyniki potwierdzają, że niedosłuch przewodzeniowy negatywnie wpływa na zdolności przetwarzania słuchowego u dzieci z CSOM, nawet u osób w wieku od 9 do 15 lat. Wyniki te wskazują na znaczenie wczesnej interwencji w przypadkach CSOM.

Słowa kluczowe: przetwarzanie słuchowe • przewlekłe ropne zapalenia ucha środkowego • dyskryminacja częstotliwościowa • dyskryminacja intensywności, wykrywanie luk

Background

Chronic suppurative otitis media (CSOM) is a common middle ear pathology occurring in childhood. This occurs especially in the first two years of life and leads to conductive hearing loss[1]. It can be unilateral or bilateral and the degree of hearing loss can be up to 40 to 50 dB[2]. CSOM can alter the sound transmission to the middle ear. These transmission changes can have detrimental effects on children as this is the time when their auditory system is maturing to process complex acoustic cues. This auditory deprivation can degrade the decoding of sound signals and impair perceptual skills[3]. There are animal studies that have documented the structural changes of the inner ear and nerves due to conductive hearing loss. Clarkson et al.(2016) speculated that long-standing conductive hearing loss can cause structural and molecular changes in the auditory nerve and brainstem nuclei[4]. In their study they used earplugs to induce a unilateral conductive hearing loss in 10 adult rats. They observed a change in absolute threshold in auditory brainstem responses before, immediately after, and 10 days after the earplugs were removed. Liberman et al.(2015) studied cochlear and neural processing by removing the tympanic membrane in one set of mice and the olivocochlear bundle in another set [5]and found a reduction in suprathreshold cochlear nerve responses. They hypothesized that a deficit in auditory processing seen in humans after persistent CSOM could be of cochlear origin.

There are many studies in the literature suggesting that long-standing CSOM may cause auditory processing disorders in children even after their hearing sensitivity returns to normal [6,7]. Most of these studies focused on children with a history of CSOM in early life and were based on parental reports of otitis media history. There is a dearth of studies that have evaluated children with later onset of CSOM and the effect of conductive hearing loss on auditory processing. The objectives of this study were to study the auditory processing abilities of 15 children of age 9 to 15 years (mean 13.4) with CSOM and compare them to normal children of comparable age. The three parameters measured were:

1. Difference limen of frequency (DLF);
2. Difference limen of intensity (DLI); and
3. Gap detection threshold (GDT).

Materials and methods

This study was done with the approval of the JIPMER ethics committee. Informed consent was taken from the participants as well as from the parents prior to the study.

Participants

The participants were divided into two groups. Group 1consisted of 15 children aged 8 to 15 years (mean age 13.4 years) with CSOM. In those children 10 had CSOM in one ear and 5 of them had CSOM bilaterally. In bilateral cases one ear was considered for the study. The pure tone average of the children in the CSOM group ranged from 20 to 60 dB HL. Group 2 comprised 15 age-and gender-matched normal hearing children. The normal hearing participants had hearing thresholds less than 20 dB from 250 Hz to 8000 Hz. Table 1 lists the details of the participants.

Stimuli and procedure

Testing was done in a double-walled sound-treated room. Detailed audiological evaluations were done for all participants. The hearing threshold was estimated using an Inventis (Piano) audiometer for frequencies 250 to 8000 Hz for air conduction and 250 to 4000 Hz for bone conduction. The modified Hughson and Westlake procedure was

Table 1. Details of the participants. CSOM = study group; NORM = control group

Participants	Age/ gender	CSOM (ear)	250	500	1000	2000	4000	8000	250	500	1000	2000	4000	PTA
		Rt/Lt/BL	AC	AC	AC	AC	AC	AC	BC	BC	BC	BC	BC	
CSOM 1	15/M	BL	40/35	50/45	40/45	40/35	50/35	30/15	5/5	0/10	15/15	15/20	0/0	45/40
CSOM 2	15/F	Lt	15/10	10/15	10/20	10/20	15/25	15/45	-5	-5	0	5	-5	11.25/20
CSOM 3	12/F	BL	30/25	35/45	45/30	35/35	25/35	25/30	5/5	5/5	5/5	10/10	0/0	35/36.25
CSOM 4	13/F	Rt	35/30	45/20	55/20	50/15	50/10	50/15	-5	-10	-10	5	0	50/16.25
CSOM 5	11/F	BL	35/25	30/30	25/20	25/25	45/50	35/30	0/0	0/0	0/0	5/10	0/0	31.25/31.2525
CSOM 6	15/M	Lt	10/45	15/55	15/60	15/55	15/55	35/50	-5/-5	-5/-5	-5/-56	0/0	-10-10	15/56.25
CSOM 7	15/M	Lt	5/20	5/30	5/30	10/25	5/35	0/50	-10/-10	-10/-5	-10/5	5/-5	0/-10	6.25/30
CSOM 8	16/M	BL	30/15	40/20	50/25	30/25	40/30	35/25	-5/-5	-5/-5	-5/-5	5/10	-5/0	40/25
CSOM 9	14/M	Rt	15/10	20/10	20/20	20/20	35/20	30/30	-10	-5	-5	5	5	23.75/17.5
CSOM 10	14/M	Rt	20/10	40/15	40/25	25/20	40/25	25/15	5/10	10/10	0/0	5/5	0/5	36.25/21.25
CSOM 11	15/M	BL	20/25	25/30	25/30	35/10	45/30	25/35	5/5	5/5	0/0	10/10	0/0	32.5/25
CSOM 12	10/M	Rt	40/5	50/10	55/15	55/10	45/15	40/5	0/0	0/5	0/5	5/15	0/0	51.25/12.25
CSOM 13	12/M	Rt	10/10	20/15	25/15	40/15	70/10	50/15	-5/0	-5/0	0/0	5/10	0/0	38.75/13.75
CSOM 14	9/F	Lt	10/30	20/55	25/60	20/35	20/55	10/55	-5/-5	0/0	5/5	5/5	0/10	21.25/51.25
CSOM 15	15/M	Lt	15/10	10/10	15/20	15/35	35/40	15/20	-5/-5	0/0	0/0	5/10	10/5	18.75/26.25
NORM 1	11/F		10/5	10/10	5/5	5/10	10/10	5/10	0	5	5	5	0	7.5/8.75
NORM 2	10/F		5/5	5/10	10/5	10/5	5/10	5/5	0	0	5	5	0	7.5/7.5
NORM 3	11/F		10/10	10/15	10/10	10/5	10/15	10/5	5	10	10	5	5	10/11.25
NORM 4	12/M		0/5	10/10	10/5	5/10	15/10	10/10	0	10	5	5	0	10/8.75
NORM 5	12/M		10/5	5/5	10/10	10/5	10/10	10/15	5	5	10	5	5	8.75/7.5
NORM 6	10/F		15/10	10/10	5/10	10/10	10/15	5/5	5	10	5	10	-5	8.75/11.25
NORM 7	8/M		5/10	10/10	10/15	15/10	10/10	10/5	5	10	10	10	5	11.25/11.25
NORM 8	12/M		10/10	5/10	5/10	5/5	10/5	5/5	0	5	5	5	0	6.25/7.5
NORM 9	10/M		5/5	10/5	5/5	10/5	5/10	10/10	5	5	0	5	5	7.5/6.25
NORM 10	12/M		5/10	5/5	10/5	10/10	10/10	10/15	5	5	5	0	0	8.75/7.5
NORM 11	8/F		15/10	10/15	10/10	15/15	15/10	10/10	10	5	10	10	5	12.5/12.5
NORM 12	14/M		5/5	5/10	5/5	10/5	10/10	5/0	0	5	0	5	-5	7.5/7.5
NORM 13	10/M		10/10	15/10	10/15	10/10	5/5	10/15	5	10	10	5	5	10/10
NORM 14	11/F		10/15	10/10	5/10	5/5	10/10	5/10	0	10	5	5	5	7.5/8.75
NORM 15	14/F		0/5	5/5	5/10	10/5	10/5	5/0	0	5	5	5	-5	7.5/6.25
CSOM mean	13.4													
Norm mean	11													

used to track thresholds [8]. Middle ear function was assessed using a GSI Tympstar Pro middle ear analyser. Tympanometry and reflexometry were done for both groups. A laptop with Psycon software (version 2.18) was used to run the test [9]. Psycon is Windows-based software designed for administrating psychoacoustic experiments. Stimuli were generated by the Psycon software using an AUX script. The paradigm employed a three interval adaptive forced choice procedure so that in each interval there was a standard and variable stimulus. The variable stimuli were presented randomly and the subject's task was to identify them. The software included two programs (psycon.exe and psycon_response.exe). In the first, the experimenter presents the stimulus as per the AUX code, and the second program allows the subject to respond. During the session, the progress of the test could be visualized on a monitor. The stimulus was delivered monoaurally at 30 dB sensational level re the participants' hearing threshold via Sennheiser HD 202 headphones.

After preliminary evaluations, those who fulfilled the inclusion criteria were included in the study. The study included administration of DLF, DLI, and GDT test.

DLF test: The difference limen frequency (DLF) was measured at a frequency of 500 Hz usinga 500 ms stimulus. A three interval alternative forced choice method with a 2-up 1-down procedure was used to estimate the DLF. Two out of three blocks on each trial contained the standard frequency and one block contained the variable frequency. The initial value of the variable frequency was close to the target frequency and the value was changed based on the subject's response. The variable frequency was presented randomly at each interval. The subject's task was to identify the box which was different in pitch. The last 4 reversals out of 8 were considered the threshold.

The AUX script for the standard interval: ramp (500, 500), 10) @-20.The AUX script for the oddball interval: ramp (500 + V, 500), 10) @-20.V denotes the amount of variation between the trials during the experiment.

DLI test: The DLI was measured at a frequency of1000 Hz. The duration of the tone was kept at 500 ms. In this procedure, there were three blocks and one block contained a tone which was louder than the other two blocks. The subject's task was to identify the block which was louder. The last 4 reversals out of 8 were considered the threshold.

The AUX script for the standard interval: ramp (1000, 500), 10) @-20.The AUX script for the oddball interval: ramp (1000, 500 + V), 10) @-20.

GDT test: The stimulus consisted of Gaussian noise of 750 ms duration and had a 0.5 ms cosine ramp at both onset and offset. This paradigm employed a three alternative forced choice method. In this test there were three blocks of white noise in each trial and in one of the blocks there was a silence of variable duration. The subject's task was to identify the block which had the silence. The length of the gap was varied depending on the subject's response. The minimum gap detected by the subject was considered the threshold.

Results

Statistical analysis was done using SPSS (version 22). The mean DLF at 500 Hz for the normal hearing children was 15.83 Hz and the CSOM group was 28.43 Hz. The mean DLI at 1000 Hz was 2.48 dB for the normal hearing children and 8.16 dB for the CSOM group. The mean GDT for the normal hearing children was 3.00 ms and that of CSOM group was 5.75 ms. In all cases, the mean values of the CSOM group were higher than for the normal hearing children. An independent *t*-test was then used to test the means between the groups. There was a statistically significant difference ($p<0.05$) for DLF, DLI, and GDT between the groups. The results are shown in Table2.

Table 2. Mean and S.D. of difference limen frequency (DLF), difference limen intensity (DLI), and gap detection threshold (GDT) and the results of independent *t*-tests

Parameter	Normal (*n*= 15)	Otitis media (*n*=15)	*p*-value
DLF (in Hz)	15.83± 0.98	28.43± 12.8	0.005*
DLI (in dB)	2.48 ± 0.9	8.16±5.48	0.005*
GDT (in ms)	3.0± 0.79	5.75±1.5	0.001*

**significant (p<0.05)*

Discussion

There are numerous studies that have demonstrated the effect of CSOM on auditory processing. However, most of the studies have recruited the subjects retrospectively. In our prospective study, we recruited children with CSOM and age- and gender-matched children served as controls. All of them underwent audiological evaluation. The degree of conductive hearing loss ranged from 20 to 60 dB HL. We evaluated the auditory processing ability of the children with CSOM in terms of frequency discrimination, intensity discrimination, and gap detection threshold. These measures are important in the coding of rapidly varying acoustic signals such as speech.

The overall performance of the children with CSOM was poorer compared to the normal hearing participants for all tests. We used GDT for measuring the temporal resolution ability, and the mean difference of the GDT between the groups was 2.75 ms, and was statistically significant ($p < 0.005$). This finding is in agreement with other studies that used the GIN test for temporal resolution and found higher values in children with CSOM[10,11].Temporal resolution ability is necessary to recognize specific features of speech and for understanding speech in adverse listening conditions [12,13]. A conductive hearing loss can delay signals reaching the cochlea as well as degrade acoustic signals. This will impair the phase-locking ability of auditory neurons. Together, these factors can contribute to the higher gap detection threshold in children with CSOM.

In the frequency and intensity discrimination tests, scores were also higher for children with CSOM. The mean differences between the groups were 12.6 Hz for DLF and 5.68 dB for DLI and these differences were statistically significant ($p < 0.005$). The maximum difference was observed for the frequency discrimination task. Similar findings have been reported in children with a past history of CSOM [14, 15].The frequency and intensity discrimination tasks require the auditory system, especially the basilar membrane, to resolve the frequency components. The poorer performance in this task can be attributed to changes in the frequency tuning of the cochlea caused by changes in the sound transmission characteristics of the middle ear.

Conclusion

The present study evaluated the auditory processing of 15 children aged 9 to 15 years with CSOM. The performance of the children with CSOM was lower compared to the normal hearing children in all the auditory processing tasks tested. The results show that children's auditory processing abilities can be affected by CSOM. Hence the study emphasizes the importance of early intervention in children with CSOM.

Acknowledgments:

We would like to thank all participants for taking part in the study.

References

1. Hogan S, Moore D. Impaired binaural hearing in children produced by a threshold level of middle ear disease. J Assoc Res Otolaryngol, 2003; 4(2):123–9.
2. Gravel JS, Wallace IF.Effects of otitis media with effusion on hearing in the first 3 years of life. J Speech Lang Hear Res, 2000; 43(3):631–44.
3. Tomlin D, Rance G. Long-term hearing deficits after childhood middle ear disease. Ear Hear,2014; 35:e233–e242.
4. Clarkson C, Antunes F, Rubio M. Conductive hearing loss has long-lasting structural and molecular effects on presynaptic and postsynaptic structures of auditory nerve synapses in the cochlear nucleus. J Neurosci,2016; 36(39):10214 –27.
5. Liberman MC, Liberman LD, Maison SF.Chronic conductive hearing loss leads to cochlear degeneration. PLoS One,2015; 10(11):e0142341.
6. Graydon K, Rance G, Dowell R, Dun BV. Consequences of early conductive hearing loss on longterm binaural processing. Ear Hear,2017; 38(5):621–7.
7. ShettyHN,Koonoor V. Sensory deprivation due to otitis media episodes in early childhood and its effect at later age: A psychoacoustic and speech perception measure. IntJPediatrOtorhinolaryngol,2016;90(Nov) :181–7.
8. Carhart R, Jerger JF. Preferred method for clinical determination of pure-tone thresholds. J Speech Hear Disord, 1959;24:330–45.
9. Kwon BJ. Psycon [Computer program]. Available from: http://auditorypro.com/download Last retrieved on 2011 Dec 19.
10. Gravel JS, Wallace IF. Listening and language at 4 years of age: effects of early otitis media. J Speech Lang Hear Res, 1992; 35(3):588–95.
11. Gravel JS, Wallace IF. Early otitis media, auditory abilities, and educational risk. Am J Speech Lang Pathol, 1995; 4(3): 89–94.
12. Rosen, S. (1992). Temporal information in speech: acoustic, auditory and linguistic aspects.Phil Trans RoySoc B,1992; 336(1278):367–73.
13. Hopkins, K, Moore BCJ, Stone MA.The effects of the addition of low-level, low-noise noise on the intelligibility of sentences processed to remove temporal envelope information. JAcoustSoc Am, 2010;128(4):2150–61.
14. Zumach A, Chenault M, Anteunis L, Gerrits E. Speech perception after early-lifeotitismedia with fluctuating hearing loss. Audiol Neurootol, 2011; 16(5):304-14.
15. Hartley D, Moore D. Effects of conductive hearing loss on temporal aspects of sound transmission through the ear. Hear Res, 2003; 177(1-2): 53–60.