



Auditory Processing Impairments Under Background Noise in Children with Non-syndromic Cleft Lip and/or Palate

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Abstract

Cleft lip and/or palate (CL/P) disorders are commonly occurring congenital malformations and hearing impairment is a very common co-morbidity. Most previous research has only focused on middle ear disorders and related auditory consequences in this group. Studies of higher level auditory status and central auditory processing abilities of this group have been unsystematic. The present study was conducted in order to objectively investigate the central auditory abilities in children with non-syndromic cleft lip and/or palate (NSCLP). A structured behavioral central auditory test battery was conducted in a group of children with NSCLP and their age/sex matched normal peers. The following behavioral central auditory tasks were undertaken, including hearing in noise test (HINT), dichotic digits test (DDT), and gaps in noise test (GIN). Results showed that there were no significant group differences in DDT test, indicating that the binaural separation and integration abilities could be normal in children with NSCLP. However, the cleft group performed significantly poorer than their normal peers for each ear in HINT test under noise condition and GIN test, suggesting that the children with NSCLP could have impaired monaural low redundancy auditory processing ability, and at risk of temporal resolution disability.

Index Terms: speech perception, auditory processing disorder, hearing impairment, cleft palate

1. Introduction

Cleft lip and/or palate (CL/P) disorders are commonly occurring congenital malformations and comprise a significant proportion of human birth defects. The majority of clefts are isolated defects, termed as non-syndromic cleft lip and/or palate (NSCLP)^[1]. Auditory impairment in patients with craniofacial clefts has been well studied for decades. Most research had focused on middle ear disorders and the related auditory consequences in this group^[2]. One possible reason might be that middle ear disorders are very common in children with CL/P and symptoms are readily noted by clinicians, while more subtle hearing disorders could be overlooked^[3]. Studies of higher level auditory status and central auditory processing abilities of this group—particularly in children—have been unsystematic and have significant limitations, while the potentially negative impact of central auditory impairment on children should not be ignored. Auditory impairment may contribute to language deficiencies, learning disabilities, and other communicative disorders in patients with CL/P, especially in children^[4]. It has been reported that children with CL/P have abnormalities in language and learning abilities, and other communicative and

cognitive disorders. Auditory impairments and cognitive disorders may account for the poor school achievement in children with CL/P^[5]. The functional consequences of hearing impairments in this group could have a rather negative impact on their quality of life and should not be under-estimated. Many reports considered the cognitive abnormalities associated with CL/P as “secondary” to factors such as middle ear diseases and consequent hearing loss^[6]. However, several reports have found that cognitive skills were not significantly affected by deficiencies in peripheral hearing. Cognitive impairment could be primary to central nervous system dysfunction^[7]. Hearing is a complex process which includes the conduction, perceptual registration, and cognitive elaboration of acoustic signals by the brain, as well as conscious perception of speech sound. Hearing impairments, whether arising from pathology of the peripheral pathway, or from dysfunction of the central auditory pathway, may have detrimental consequences on a child's life if untreated.

Structural brain abnormalities in patients with NSCLP have been reported, particularly, the malformation of the central auditory nervous system (CANS) was noted. Researchers reported structural malformation of the superior temporal plane (STP) of subjects with NSCLP compared to normal controls^[8]. As STP is a brain region of the CANS which is believed to be involved in high level auditory processing, it is worthwhile to investigate whether auditory function is affected in individuals with NSCLP. Studies using magnetic resonance image (MRI) brain scan found that the pattern of brain abnormalities in children with NSCLP was different from that noted in adult subjects with clefts, suggesting that brain development might be abnormal in children with NSCLP^[9]. In addition, studies had reported cortical auditory dysfunction reflected by abnormal auditory event-related potentials (ERPs) in children with NSCLP, indicating that the high level auditory disabilities might exist in this group^[10,11]. Furthermore, auditory behavioral studies had reported that children with NSCLP appeared to have some overt behavior indicative of auditory disabilities, and scored significantly lower in the central auditory tests comparing their normal peers^[12]. These studies could lead to a same conclusion that subjects with craniofacial clefts were potentially at risk of high level auditory dysfunction, or auditory processing disorders (APD). APD could have negative impacts on speech and language development, communication problems and learning deficits^[13], and need to be further investigated. However, to date, data on central auditory function in children with CL/P are limited, particularly, in Chinese speaking children with NSCLP. The present study aimed to observe the central auditory abilities in this group, using structured behavioral central auditory test battery approach.

2. Auditory Behavioral Tests

The current study has been approved by the Institutional Review Board of the University of Hong Kong/Hospital Authority West Cluster (HKU/HA IRB, protocol Number UW 07- 250). This study was conducted in collaboration with the Cleft Lip and/or Palate Center, Shenzhen Children's Hospital, and the Shenzhen Second Experimental Middle School. Formal consent forms were acquired from the parents or guardians of all subjects who participated in the present study.

2.1 Participants

For the NSCLP group, children were recruited from the Cleft Lip and/or Palate Center, Shenzhen Children's hospital. Before the auditory behavioral tests, peripheral hearing status assessments including otoscopic examination, tympanogram, acoustic reflex, TEOAE screening and pure tone audiometer hearing threshold acquisition (500, 1000, 2000, and 4000 Hz) were conducted. Subjects with peripheral hearing impairments were excluded from the current study in order to reduce the impact of conductive and sensory-neural hearing loss on the auditory processing abilities.

Eighteen subjects aged from 7 to 15 years old, with normal middle and inner ear function and normal hearing levels were included in this study. The mean age of the NSCLP group was 11.33 years (SD=2.08 years). All participants in the NSCLP group were Han Chinese from mainland China. The subject characteristics of the NSCLP group are summarized in Table 1. Eighteen age/sex matched typical developed children were recruited as the normal control group.

Table 1: *Subject characteristics of the NSCLP group.*

Cleft type *	Gender		Cleft status	
	Male	Female	Unrepaired	Repaired
LUCP±L	3	1	0	4
RUCP±L	3	1	0	4
BCP±L	3	1	0	4
CP	0	3	0	3
CL±A	1	2	0	3

2.2 Hearing in noise test

The HINT test was developed by Nilsson et al. and the standardized HINT test (House Ear Institute, USA, version 5.0) is commercially available. The original purpose for HINT is to evaluate the speech perception ability of the subjects in quiet and noise conditions [14]. For children, test materials comprise 15 lists of Mandarin sentences and each list is composed of 10 sentences with ten Chinese characters. Sentences were delivered monaurally to subjects in quiet and noise conditions. There was no background noise in the quiet condition, while the speech sentences were embedded in background noise which is fixed to 65 dB HL in the noise condition. Subjects were required to repeat all parts of the sentences that they heard. The intensity of the speech signal was degraded by 2 or 4 dB automatically according the response of the subjects, to

determine the reception threshold for sentences (RTSs) of the subjects.

2.3 Dichotic digits test

The DDT test was used in order to assess dichotic listening or binaural separation and integration abilities. The Mandarin Dichotic Digit Test (MDDT) was developed by researchers of the University of Hong Kong [15]. Three digit tasks were presented using the CD-ROM player of a laptop computer (Dell TX 620) through the audiometer and headphones (TDH-39A, Telephonics, USA) at an intensity of 60 dB HL. Subjects were asked to repeat each set of three numbers they heard. There were two conditions, directed recall and free recall. In the directed recall condition, subjects were required to repeat the numbers they heard in a specified ear in any order and to ignore the numbers delivered to the other ear. In the free recall condition the subjects were required to repeat all numbers they heard from both ears in any order. The percentile of correctly reported numbers was recorded for analysis.

2.4 Gap in noise test

The commercially version of the GIN (Audiology Illustrated, USA) was applied in the current study. The test is composed of four different lists contain a series of up to 36 different six-second white noise segments. Each of the white noise segments contains from 0 to 3 gaps of silence and these gaps appear anywhere within the noise segment. The duration of the gaps are 2, 3, 4, 5, 6, 8, 10, 12, 15 or 20 milliseconds. The gaps are randomized in their occurrences. The test aim is to determine the smallest gap (in terms of time) that can be detected in each ear. Test stimuli were presented monaurally using the CD-ROM of a laptop computer through the audiometer and headphones at 60 dB HL. One test list is given in each ear for one subject. There is a practice section to ensure each subject understands the test procedure. Subjects were required to press the response button as quickly as they can when they detected the "gap" in the noise segment. The smallest gap (in terms of time) that can be detected was considered as the threshold for the GIN test.

All test materials for APD assessment were recorded in CDs and tests conducted using a laptop computer through an audiometer (204A, Entomed, Sweden). The intensity of all auditory stimuli was calibrated with a Brüel & Kjær acoustic calibration system (Brüel & Kjær, Demark) using a pre-recorded 1000 Hz pure tone sound track for calibration purposes. All the procedures of central auditory tasks detailed above were carried out individually in one session of about 60 minutes, there were rest periods given to children throughout the session to avoid fatigue effects. The auditory behavioral tasks were given at a randomized order.

3. Results

Statistical analysis was performed using the SPSS version 16 statistical package. Nonparametric statistics were used to compare the performance between control and NSCLP groups. Tests results were compared between groups for significant differences using Mann-Whitney U tests.

3.1 Hearing in noise test

There is no significant difference between groups for HINT in the quiet condition for each ear, but significant difference were found between children with NSCLP compared to the normal

controls for HINT in noise condition for each ear. Children with NSCLP performed significantly poorer than their normal peers.

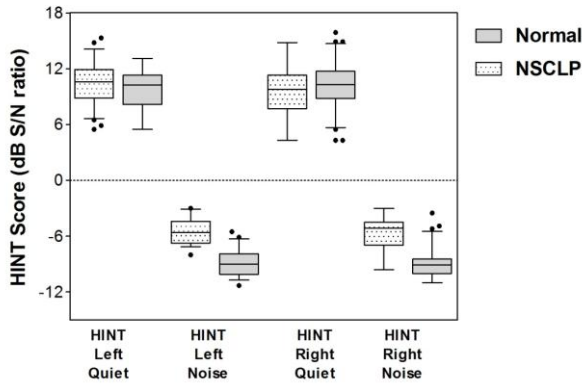


Figure 1: Box-plots showing HINT scores for both ears in different conditions in normal and NSCLP groups.

Figure 1 shows the box-plot graph of HINT test results in both groups and table 2 shows the statistical analysis results for the group comparison.

Table 2: Results of statistical analysis for group comparison in HINT test.

Test condition	Mann-Whitney U	Z	P (2-tailed)
HINT Left (Quiet)	498.00	-0.962	0.336
HINT Left (Noise)	43.50	-5.997	< 0.001*
HINT Right (Quiet)	550.50	-0.381	0.703
HINT Right (Noise)	101.00	-5.362	< 0.001*

3.2 Dichotic digits test

Most subjects in both groups scored higher than 95% correct in any test conditions. There was no statistically significant difference between the NSCLP group and normal controls in any test conditions.

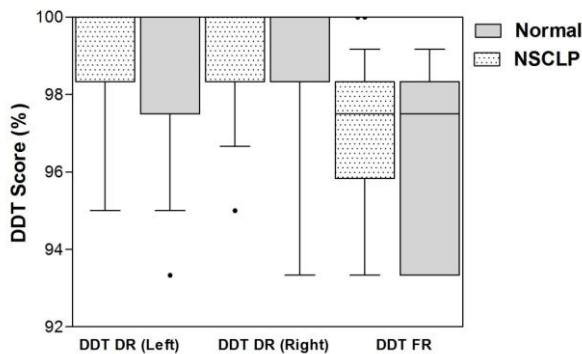


Figure 2: Box-plots showing Mandarin DDT test scores for each ear in different conditions.

Figure 2 shows a box-plot graph of DDT test results in both groups and table 3 shows the nonparametric statistical results for group comparison.

Table 3: Results of statistical analysis for group comparison in DDT test.

Test condition	Mann-Whitney U	Z	P (2-tailed)
DDT DR Left	584.50	-0.447	0.655
DDT DR Right	581.00	-0.050	0.960
DDR FR	531.50	-0.600	0.548

3.3 Gap in noise test

Figure 3 shows the box-plot graph of GIN test results in both groups for each ear. The results show that there was a significant group difference between groups (Mann-Whitney U=397.00, Z=-2.192, P=0.028 for left ear and Mann-Whitney U=548.50, Z=-0.447, P=0.008 for right ear). Children with NSCLP were found to have significantly lower scores in both ears compared to normal controls. The GIN gap detection thresholds for both groups were found to be at normal range according to the norms for school aged children provide by the developer, which range from 4 to 8 milliseconds^[16].

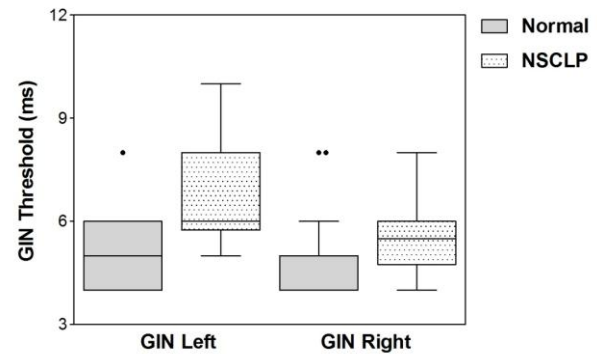


Figure 3: Box-plots showing GIN test scores in normal and NSCLP groups.

4. Discussion and Conclusion

In the present study, evidence showed that children with NSCLP group could be at risk of APD. Considering the negative impact of APD on children's development of speech and language, further studies need to be conducted.

For behavioral central auditory tests, there have been a great variety of suggested diagnostic tests^[7]. However, for Chinese verbal tests, there were few test materials currently available, particular with a Mandarin version. We applied one test for each ASHA consensus category of auditory processing abilities in the present study. For monaural low redundancy assessment, we applied the modified HINT test. DDT test (Mandarin version) and GIN tests was applied for binaural separation, integration and temporal resolution assessment. Such a test battery could only provide basic information of the central auditory processing abilities in subjects, including verbal and non-verbal auditory skills^[17]. Results showed no statistically significant differences between the control and study groups in DDT test and HINT test of quiet conditions, indicating that no differences between the groups for the hearing functions of binaural processing or dichotic listening, temporal sequencing and speech discrimination in quiet were

found in the present study. However, subjects in the NSCLP group were found to be more adversely affected than the controls in HINT test of noise condition. This suggests that children with NSCLP may have difficulties in understanding speech in the presence of background noise. In addition, although the test results were found to be within the normal range in the GIN test, the group of children with NSCLP performed significantly poorer than did normal controls. As the HINT in noise condition and GIN are all noise-related tests, it is reasonable to suspect that children with NSCLP may have hearing difficulties in the presence of background noise. However, such a prediction does not yet have enough supportive experimental data and should be further investigated in future research.

The central auditory tests which were applied in current study have been suggested as appropriate for auditory processing assessments in school aged children by other studies^[7]. The modified HINT was applied in the present study. In this HINT test, the competing noise was presented at a fixed level (65 dB HL) while the levels of target sentences were adjusted by 2 or 4 dB HL to determine the reception threshold for sentences (RTSs, i.e., +10, 0 -10 dB HL). Results of the HINT test showed that children with NSCLP performed significantly poorer than normal controls who participated in the present study, in the noise condition. Considering this significant result, it is reasonable to argue that these subjects may be at risk of APD, or they might have speech discrimination difficulties in background noise conditions, which was considered as a part of ADP for monaural low redundancy assessment. It is interesting that the HINT test, which does not suffer from ceiling effects, gave the significant result obtained from the present study. One possible explanation could be that the test materials were speech sentences, which were more complicated auditory stimuli than the acoustic input applied in the other central auditory tasks, and the school aged children with NSCLP who were subjects participating in this study might have more difficulties in processing complex auditory information rather than simple acoustic stimuli. Alternatively, this result may be due to greater sensitivity of the HINT test, derived from its more normal distribution of results. However, no significant differences between groups in HINT in quiet condition were found in current study. This finding may indicate that children with NSCLP could show normal auditory processing ability in speech discrimination when an ideal listening environment is provided. The Mandarin version of the DDT test was used and this is a newly developed test specially designed for Mandarin speakers. No systematic research with a large sample size has been conducted yet to investigate the sensitivity, specificity, validity, and reliability for this version of DDT. It has been reported that increasing the complexity of the test materials, especially over a restricted time period, would require a greater demand on auditory processing and therefore could reduce ceiling effects in the dichotic listening test. Dichotic sentences, rather than digits, might provide better validity and could be considered in the future studies. GIN test was applied to assess the auditory temporal resolution or discrimination abilities in subjects. The sensitivity and specificity of GIN test were reported to be 72% and 94%, respectively and it seems that the GIN test is more sensitive to cortical impairment rather than brainstem lesion^[16]. In the present study, the results of GIN test were also found to be in the normal range (from 2 msec to 6 msec in school aged children) advised by the developers and noted in other reports^[17]. There was a statistically significant difference between

study and control groups in GIN results, suggesting that the children with NSCLP could be at risk of temporal resolution disability, however, the results of the GIN test in the present study should also be interpreted cautiously, as the data acquired in both groups were in the normal range compared to the normative data.

In summary, the current study assessed the auditory processing abilities in a group of children with NSCLP with a newly developed APD assessment protocol. Results provided additional data related to the research hypothesis that patients with craniofacial clefts are at risk of central auditory impairments, and revealed that the children with NSCLP showed significantly poorer speech discrimination in noise conditions in comparison to normal children. APD may be the underlying factor of these differences in test results. The test protocol applied in current study could detect auditory skills disorders in the target population. However, modifications in test materials are necessary for future studies.

5. Acknowledgments

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