Nasalance scores of Egyptian hearing impaired children

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Context
Speech of prelingual hearing impaired (HI) speakers is commonly characterized by the presence of resonance abnormalities which is related with nasality.

Aim
To investigate and compare nasalance scores of Egyptian HI children including cochlear implant (CI) and hearing aid (HA) users with normal hearing (NH) children.

Settings and design
It is an observational case–control study.

Patients and methods
The study consisted of group I: 41 HA children, group II: 24 CI children, and the control group: 31 age-matched and sex-matched children with NH. Nasometer II 6200 was used for evaluation of their nasalance scores.

Statistical analysis used
IBM SPSS, version 20, was used. Kruskal–Wallis and one-way analysis of variance tests were performed to compare the mean differences between the nasalance scores of the three studied groups. While Mann–Whitney and post-hoc tests were used for pairwise comparison. A correlation analysis was computed between the nasalance scores and many parameters using Spearman's and Pearson's coefficients.

Results
For oral sentence, both CI and HA children showed higher nasalance values in comparison with NH children. However, lower nasalance scores were observed for the nasal sentence. CI experience and enrollment into language therapy were found to have an effect on nasalance scores.

Conclusions
Resonance quality of the HI children is still at risk despite the fact that a significant number of them demonstrate normal resonance.

Keywords:
Egyptian children, hearing impaired, nasalance scores

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Introduction

Hearing is essential for speech development in children. Resonance is often a problem in the speech of prelingually deaf children [1–3].

A number of authors have identified the resonance disorder as hypernasality [4–10]. Habitually nasalized resonance was also reported [11]. However, a number of studies suggested hyponasality [12]. Other studies demonstrated a cul-de-sac resonance [13,14].

The study aims to compare the nasalance scores of Egyptian hearing impaired (HI) children including cochlear implant (CI) and hearing aid (HA) users with values of age-matched and sex-matched normal hearing (NH) children. Also investigate a possible correlation between the nasalance scores and different parameters.

Patients and methods

Ethics

The approval of the Ethics Committee of Faculty of Medicine of the followed university was obtained before initiating the study.

Study design

It is an observational case–control study. It was carried out during the period from June 2016 to June 2017.

Patients

Group I comprised of 41 children who were binaurally fitted with digitally programmable HAs.

Group II consisted of 24 cochlear implantees using a unilateral multichannel CI.

The control group: 31 age-matched and sex-matched children with NH.

Individual selection criteria are:
(1) Inclusion criteria:
   (a) Prelingual HI children with HA or CI.
   (b) Age: 4–12 years.
   (c) Sex: both sexes were included in the study.
(2) Exclusion criteria: included the presence of
   (a) Structural anomalies of the palate (e.g. cleft palate).
   (b) Neuromuscular disorders.
   (c) Mental affection.
   (d) Common colds and nasal congestion.

Methods

Protocol of assessment for individuals

According to Kotby *et al.* [15] the following steps were applied to each patient.

(1) Elementary diagnostic procedure:
   (a) Patient interview: data collected from the parents were age of the child, sex, degree of hearing loss, age onset and duration of hearing loss, age onset and duration of HA or CI (calculated from the age onset of hearing loss up to the age of amplification for both groups), enrollment into language therapy and if so its duration.
   (b) Auditory perceptual assessment of speech.
   (c) Clinical examination: visual assessment of vocal tracts. Also, simple clinical tests such as Gutzman's (a/i) test and Czermak's (cold mirror) test were performed.
(2) Clinical diagnostic aids:
   (a) Psychometric tests.
   (b) Basic audiological evaluation.
(3) Instrumental aids: Nasometer II 6200 (Kay Elemetrics/PENTAX [Pine Brook, New Jersey (NJ) , USA]) was used to measure nasalance scores after calibration. Nasalance score is expressed as a percentage and reflects the ratio of nasal acoustic energy to total acoustic energy.

Speech material for nasometry

The first speech task was to ask each patient to sustain three vowels (/a/,/i/,/u/) and one consonant/m/. The second speech task was to ask the older children (8–12 years) to repeat two sentences, an oral and nasal one, three times and their mean was taken.

Analysis and statistics

IBM SPSS (IBM Corp., Armonk, New York, USA) software package, version 20 was used for statistical analysis. The Kolmogorov–Smirnov test was used to verify the normality of distribution. The results for the CI, HA, and NH children were compared. In case of normally distributed data (nasalance scores of nasal sentence for the three studied older groups), a 'one-way analysis of variance' in combination with a *post hoc* was applied. When a deviation from a normal distribution occurred (nasalance scores of first task for the three studied groups and those of oral sentence for the older group), Kruskal–Wallis tests were used to document possible differences between them. When the gained P value was smaller than 0.05, pairwise comparisons were performed using a Mann–Whitney test. The Spearman's correlation coefficient was measured to correlate between the abnormally distributed data and different parameters, whereas Pearson's coefficient was used for the normally distributed ones.

Results

Sixty-five prelingually Egyptian HI children were selected to participate in this study. They have been categorized into two main groups.

Group I

HA children [41 children: 25 (61%) boys and 16 (39%) girls, with 25 (61%) of them between the age of 4 and 8 years and 16 (39%) between the age of 8 and 12 years] consisted of 19 (46.3%) HI child with average better ear pure tone thresholds 56–90 dB and 22 (53.7%) children more than or equal to 90 dB. The mean age onset of hearing loss in HA group is 1.84 years (range, 0.25–5.0 years) with mean hearing loss duration 1.01 years. HA children had received their first HAs at mean age of 2.81 years with mean duration of 4.43 years. Thirty-five (85.4%) HA children had attended language therapy with mean duration 3.35 years and six (14.6%) children had not.

Group II

CI children [24 children: 10 (41.7%) boys and 14 (58.3%) girls, with 15 (62.5%) of them between the age of 4 and 8 years and nine (37.5%) between the age of 8 and 12 years). One (4.2%) HI child with average better ear pure tone thresholds 56–90 dB and 23 (95.8%) children more than or equal to 90 dB, with mean age of hearing loss at 1.04 years, the mean hearing loss duration 0.82 years. CI children had received their multichannel CI at mean age of 4.80 years with mean experience of 1.29 years. Only three (12.5%) children had not received language therapy whereas the remaining 21 (87.5%) children had received it with mean duration 1.21 years.

And the third control group NH children [31 children: 22 (71%) boys and nine (29%) girls, with 20 (64.5%) of them between the age of 4 and 8 years and 11 (35.5%) between the age of 8 and 12 years].

They were subjected to nasometer to evaluate their nasalance scores.

On data analysis we found that:

(1) For the first speech task (sustain/a/,/i/,/u/, and/m/ sounds) for all patients (Table 1): there was no significant statistical difference in nasalance scores between the three groups.
(2) For the second speech task (oral and nasal sentences) for older children (Table 2):
    (a) The mean nasalance scores for the oral sentence was significantly increased in the HA and CI children, compared with the NH group. On the other hand, the CI group showed statistically nonsignificant lower nasalance scores than those of HA children.
    (b) For the nasal sentence, statistically significant decreased nasalance scores were found in the HA and CI groups compared with the NH group. Furthermore, compared with the HA groups, the CI children showed lower nasalance scores with significant statistical difference.

It was found that there is statistically significant negative correlation between the duration of CI and nasalance scores of/a/,/i/, and/u/vowels (Table 3). Other parameters show no correlation.

There is statistical significant positive correlation between nasalance scores of nasal sentence and attendance of language therapy. Other parameters show no correlation (Table 4).

Discussion

The present study aimed to investigate and compare nasalance scores in 41 HA users and 24 CI children to 31 NH children.

On statistical analysis of nasalance scores

For the first speech task (/a/,/i/,/u/, and/m/sounds) for all children:

The statistically nonsignificant difference of nasalance scores regarding/a/,/i/,/u/vowels and/m/consonant for the HA and CI children to the NH control group is consistent with the findings of Van Lierde *et al*. [16]. However, Baudonck *et al*. [17] reported that the CI and HA groups had significant lower nasalance scores for the isolated consonant/m/compared with the NH control group.

On the other hand, these results disagree with Mythri *et al.* [18] who reported increased nasalance values in 15 children with HI regarding the three vowels with highest nasalance value for/i/followed by/u/and/a/compared with NH children. The difference between the results of the present study and that of Mythri and colleagues could be explained by the lower number of HI children participated in the latter study along with the unaided condition (no HA or CI) of their hearing loss.

Table 1 Comparison between the three studied groups according to vowels and/m/nasalance scores

Vowels and/m/nasalance scores	Group I: hearing aid (*n*=41)	Group II: cochlear implant (*n*=24)	Group III: control (*n*=31)	*H*	*P*
/a/					
Minimum-maximum	2.66-20.27	2.67-12.70	3.40-15.44	0.407	0.816
Mean±SD	8.50±4.05	7.79±3.18	7.68±2.67		
Median	7.22	8.44	7.10		
/i/					
Minimum-maximum	6.09-39.94	6.56-35.06	7.0-39.84	5.044	0.080
Mean±SD	20.45±8.07	16.91±7.28	21.64±8.20		
Median	19.90	16.42	20.66		
/u/					
Minimum-maximum	3.22-22.64	1.08-15.17	4.78-26.0	3.923	0.141
Mean±SD	10.98±4.78	8.74±3.99	11.58±5.23		
Median	11.33	8.44	10.65		
/m/					
Minimum-maximum	82.59-96.89	82.58-97.22	80.28-96.84	5.622	0.060
Mean±SD	93.85±2.84	91.0±4.83	93.17±3.61		
Median	94.46	92.28	94.11		

H, *P*, *H* and *P* values for Kruskal-Wallis test.

Table 2 Comparison between the three studied groups according to oral and nasal sentences in older age group (8-12 years)

Vowels and/m/nasalance scores	Group I: hearing aid (*n*=16)	Group II: cochlear implant (*n*=9)	Group III: control (*n*=11)	Test of significance	*P*
Oral					
Minimum-maximum	8.36-46.56	21.58-36.67	9.50-27.90	*H*=11.070¶	0.004¶
Mean±SD	29.99±10.59	28.87±7.05	18.03±6.32		
Median	28.82	28.87	17.57		
Significance between groups	P_1=0.571, P_2=0.004¶, P_3=0.004¶				
Nasal					
Minimum-maximum	43.30-72.71	41.21-56.18	54.47-72.90	*F*=7.860¶	0.002¶
Mean±SD	56.22±10.52	49.06±5.17	63.88±6.55		
Median	53.20	48.89	63.92		
Significance between groups	P_1=0.047¶, P_2=0.025¶, P_3<0.001¶				

H, P, H and *P* values for Kruskal-Wallis test, significance between groups was done using Mann-Whitney test. *F, P, F* and *P* values for analysis of variance test, significance between groups was done using post-hoc test (least significant difference). P_1, *P* value for comparing between hearing aid and cochlear implant. P_2, *P* value for comparing between hearing aid and control. P_3, *P* value for comparing between cochlear implant and control. ¶Statistically significant at *P* value less than or equal to 0.05.

Table 3 Correlation between vowels and/m/nasalance scores and different parameters in whole patient groups

	Vowels and/m/nasalance scores			
	/a/	/i/	/u/	/m/
Degree of hearing loss (dB) for HA and CI (*n*=65)				
r_s	−0.183	−0.088	−0.218	−0.025
P	0.145	0.487	0.081	0.846
Age onset of hearing loss (years) for HA and CI (*n*=65)				
r_s	0.052	0.115	0.081	0.131
P	0.682	0.363	0.520	0.299
Duration of hearing loss (years) for HA and CI (*n*=65)				
r_s	0.003	0.044	−0.115	0.162
P	0.982	0.727	0.363	0.199
Attendance of language therapy or not for HA and CI (*n*=65)				
r_s	−0.097	−0.077	−0.076	0.169
P	0.440	0.541	0.548	0.179
Duration of language therapy (years) for HA and CI (*n*=65)				
r_s	−0.261	0.053	−0.155	0.194
P	0.052	0.696	0.254	0.151
Age onset of HA fitting (years) for HA (*n*=41)				
r_s	−0.122	−0.040	−0.045	−0.069
P	0.446	0.805	0.782	0.668
Duration of HA fitting (years) for HA (*n*=41)				
r_s	−0.252	−0.114	−0.204	0.225
P	0.112	0.479	0.201	0.157
Age onset of CI (years) for CI (*n*=24)				
r_s	0.283	0.048	0.033	0.185
P	0.180	0.822	0.880	0.388
Duration of CI (years) for CI (*n*=24)				
r_s	−0.478†	−0.435†	−0.525†	0.033
P	0.018	0.034	0.008	0.877

CI, cochlear implant; HA, hearing aid; rs, Spearman coefficient.
†Statistically significant at *P* value less than or equal to 0.05.

For the second speech task (oral and nasal sentences) for children aged 8–12 years:

The statistically significant difference of mean nasalance scores of the oral sentence for the HA and CI older children to the NH of same age group, reflecting the presence of hypernasality, is in agreement with studies applied on HA children described by Fletcher and Daly [6] in addition to LaPine *et al.* [9]. Also consistent with results of studies applied to CI along with HA children by Baudonck *et al.* [17] and Sebastian *et al.* [19].

Stevens *et al.* [5] illustrated that the increase in nasal resonance in these patients has been attributed to the faulty posterior posturing of the tongue, or to inefficient control of the velopharyngeal valve as a consequence of absent auditory feedback.

The present study also shows that the mean nasalance scores for the CI children are nonsignificantly lower than that of HA children.

These results were inconsistent with results of the study applied on CI children by Svirsky *et al.* [10] who reported values closer to normal when the devices were on. Also, a study conducted on CI and HA children by Sebastian *et al.* [19] had demonstrated that nasalance scores of the cochlear implantees were significantly lower than that of the HA users but did not match with the normal controls. Although, Monini *et al.* [20], Nguyen *et al.* [21], and Baudonck *et al.* [17] had reported a normalization of the increased nasality after implantation. So, those studies suggest that the speech of the cochlear implantees was superior to that of the HA users. This could be explained by their good auditory verbal therapy and earlier age of implantation.

For the nasal sentence, significant decreased nasalance scores were found in the HA and CI groups compared with the NH group.

This is indicating hyponasality in HA and CI children. These findings are in line with the suggestions of Monini *et al.* [20] and Svirsky *et al.* [10], that nasal resonance is reduced after CI activation.

Also, compared with the HA group, the CI children in this study showed significant hyponasality.

Table 4 Correlation between oral and nasal sentences nasalance scores with different parameters

	Oral		Nasal	
	r_s	*P*	*r*	*P*
Degree of hearing loss (dB) for HA and CI (*n*=25)	0.251	0.226	0.049	0.816
Age onset of hearing loss (years) for HA and CI (*n*=25)	−0.113	0.591	−0.115	0.583
Duration of hearing loss (years) for HA and CI (*n*=25)	0.263	0.203	−0.102	0.626
Attendance of language therapy or not for HA and CI (*n*=25)	0.057	0.787	0.605‡	0.001
Duration of language therapy for HA and CI (*n*=25)	−0.085	0.686	0.227	0.276
Age onset of HA fitting (years) for HA (*n*=16)	−0.117	0.667	−0.486	0.056
Duration of HA fitting (years) for HA (*n*=16)	0.050	0.853	0.661	0.005
Age onset of CI fitting (years) for CI (*n*=9)	0.080	0.838	−0.320	0.402
Duration of CI fitting (years) for CI (*n*=9)	−0.298	0.436	−0.009	0.981

CI, cochlear implant; HA, hearing aid; r_s, Spearman coefficient; *r*, Pearson's coefficient. Statistically significant at *P* value less than or equal to 0.05.

This finding was in agreement with Van Lierde *et al.* [16] and Baudonck *et al.* [17] who found that the CI children had significantly lower nasalance percentages in comparison with the HA children. The lower nasalance scores for the CI children on the nasal sentence must be interpreted cautiously because no differences were measured for the sound/m/. The reason for the decreased nasal resonance in the nasal sentence for the CI children requires further research.

Those alternating hyponasal and hypernasal results may demonstrate the absence of adequate control of the nasal–oral balance in severely HI children with CI or HA. This phenomena was already described by Boone *et al.* [13] and Fletcher *et al.* [8] in HA children, and by Baudonck *et al.* [17] with HA and CI children.

The discrepancy between normative nasalance scores for sounds (vowels and/m/) and the deviant nasalance scores for sentences, in both HA and CI children can be attributed to the better auditory feedback for short stimuli/a/,/i/,/u/, and/m/with the aid of visual and tactile clues given by the investigator. Moreover the absence of misarticulation regarding those simple sounds, which is not the case for the connected speech.

The correlation between the nasalance scores and multiple variables

There is a highly significant negative correlation between the duration of implantation and nasalance scores for/a/,/i/, and/u/vowels. It means that the longer the implantation experience, the lower the nasalance scores.

On the other hand, there is a highly significant positive correlation between enrollment into language therapy and the nasalance scores for nasal sentence. This should be interpreted cautiously as the small number of those who did not receive language therapy may affect the results.

Conclusion and recommendations

Resonance quality of the HI children is still at risk despite the fact that a significant number of them demonstrate normal resonance. The outcome of the present study would lead the attention to assess nasality in HI children for early intervention and proper management. The study recommends future detailed analysis in a larger sample of CI and HA older children, performing oral and nasal sentences, which may further help to clarify the resonance characteristics and reveal an important prognostic value. It also recommends investigating the effect of their deviant nasality to overall speech intelligibility.

Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent forms. In the form the patient(s) has/have given his/her/their consent for his/her/their images and other clinical information to be reported in the journal. The patients understand that their names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

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Conflicts of interest

There are no conflicts of interest.

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