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The effect of otitis media with effusion on phonological performance of preschool children

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Abstract

Objectives Phonological development is dependent on the integrity of the auditory system. Otitis media with effusion (OME) may affect speech perception in children and therefore phonological development. The aim of this study was to investigate the impact of persistent OME on the phonological performance of preschool children.

Methods Sixty children with persistent OME who were candidates for myringotomy and ventilation tube insertion were included in this prospective observational study. We assessed their phonological skills before and after surgery (3 and 6 months) by phonological production tasks that included calculation of percentage of consonants correct (PCC) and process density index (PDI).

Results We detected preoperative poor phonological performance in 91.7% of children. We found statistically significant differences in PCC and PDI between the three time periods. Also, there was a significant improvement after 6 months compared to 3 months.

Conclusions OME has an adverse consequence on the phonological performance of preschool children, it can affect different domains such as PCC and PDI. The findings of this study revealed that myringotomy with ventilation tube insertion for children with persistent OME could aid in the development of intact phonological skills.

Keywords Otitis media with effusion, Phonological performance, Myringotomy, Preschool children

Background

Otitis media with effusion (OME) is characterized by the accumulation of fluid in the middle ear cavity. Its cause is usually Eustachian tube dysfunction, and it may follow acute otitis media (AOM) [1]. It is one of the most common medical problems among preschool children, approximately 80% of children have had OME by the age of 4 years but a decline in prevalence is observed for children beyond the age of 6 years [1, 2]. Although most episodes of OME in children resolve spontaneously within 3 months, 35% of those children may suffer periodic attacks [3]. Most children with OME experience mild to moderate degrees of conductive hearing loss (CHL) [4]. It has been reported that the average hearing threshold for those children is about 25 dB; however, it may range from 0 to 50 dB [3]. Watchful observation is the preferred strategy for the treatment of OME except for children who have hearing impairment or delayed speech acquisition. The concern over the consequences of OME in relation to language and speech development results in considering myringotomy with ventilation tube insertion (MVT) to be done [5]. Also, adenoidectomy is an important addition to the management of those children [6].

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The recurrent nature of OME with fluctuating hearing loss for extended periods would modify the consistency and stability of the auditory signals. Thus, exposure to distorted speech signals may have a negative impact on a child's phonological acquisition during the crucial years of phonological development [7]. So, the disease may lead to the formation of incomplete phonological categories and continuity of using phonological processes in language [8]. Phonological processes are systematic alternations in the sound classes, sound sequences, or syllable which used to simplify the pronunciation of words in a language. The use of phonological processes is typically discontinued by the time the child reaches a certain developmental age, but if they persist, they can be a sign of delayed phonological development [9].

The impact of OME on speech and language development has been studied before [10]; however, its effect on phonological performance has not been well-addressed in the literature. It is important to ascertain the effects of OME on phonological skill development and to follow up on the consequences of treatment. Such a study could help clinicians to manage children with OME in a timely manner and to be able to provide information to parents of children with recurrent OME regarding the risk for phonological delay. The aim of this study was to investigate the impact of persistent OME on the phonological performance of preschool children.

Methods

Participants

Sixty children with persistent OME who were candidates for MVT were included in this prospective observational study. The patients' ages ranged between 4 and 6 years (mean of 5.2 ± 0.6 years), 38 were males and 22 were females. The indication for MVT was OME in both ears persistent for more than 3 months, with diminution of hearing, and confirmed on tympanometry at the time of diagnosis and at the end of the watchful waiting period (3 months). Surgical intervention was performed within a week after the failure of watchful waiting according to the policy of our institute. Children who had OME in one ear, who had ear problems other than OME, who underwent previous ear surgery, and who had a mental disability were excluded from the study. Twenty normal age-matched children, 10 males and 10 females, were included in the study as a control group. Parental informed consent was obtained for all patients, and we adhered to the principles outlined in the Declaration of Helsinki. The protocol of the study was approved by the research ethics committee of our institute (N-126–2023).

Procedures

All patients who demonstrated failure of watchful waiting were subjected to:

Otolaryngologic assessment

A detailed history was taken from the parents including a history of the diminution of hearing, other ear symptoms, and other ENT problems. Otoscopic examination and tympanometry were performed for all children. Also, a full otorhinolaryngologic examination was done including facial, nasal, oral cavity, and oropharyngeal inspection. Pure tone audiometry and speech discrimination were used for hearing evaluation in cooperative children. Pure tone audiometry using Interacoustics AC40 clinical audiometers (Interacoustics, Middelfart, Denmark) was done, in a sound-treated room (Amplisilence model E, Milano, Italy), and a TDH 39 earphones (Telephonics, NY, USA). The device was calibrated according to the ISO standard. Tonal audiometry was done in the frequency range of 0.25–8 kHz. Speech audiometry was done to detect speech reception threshold (SRT), using Arabic spondee words and word discrimination score (WDS), using Arabic phonetically balanced words spoken by the examiner's live voice at a 35–50-dB sensation level in reference to the patient's SRT or at the listener's most comfortable level (MCL).

Preoperative phonological assessment

Expressive phonological performance (EPP) was assessed within the week before surgery, using the phonological production task (Arabic version) [11]. This task was developed to elicit children's single-word productions with a picture-naming speech sample, it consisted of 69 Arabic words containing instances of all Arabic consonants and vowels in different syllabic templates with sufficient opportunities. Children were instructed to name the pictures that were presented to them sequentially; each picture was used to elicit only a single word, and spontaneous responses and responses from delayed imitations were counted.

The test was carried out in a quiet environment and all sampling were audio-recorded to facilitate analyses. Children's consonant production and phonological simplification processes were analyzed. The percentage of consonants correct (PCC) and process density index (PDI) were used in evaluating the phonological performance. PCC was calculated by dividing the number of correct consonants produced by each child by 224 which is the number of total consonants in the picture naming speech sample then multiplied by 100 [12]. PDI was calculated based on the number of phonological processes that occurred in each word divided by the total number

of words [13]. The PDI is inversely related to the PCC as a consonant that is not produced correctly is affected by at least one process. The cut-off levels for diagnostic accuracy of PCC and PDI in predicting phonological disorder are 96.6% and 0.14% respectively. Children with a PCC score of less than 96.6% and/or with a PDI score of more than 0.14% are considered to have phonological disorders [11].

Operative intervention

Under general anesthesia, adenoidectomy was performed regardless of adenoid size as a routine procedure for those children (with persistent OME) in our institute. It was done by conventional curettage method with endoscopic inspection of the nasopharynx at the end of the procedure [14]. Myringotomy was done in the anteroinferior quadrant of the tympanic membrane, with the insertion of a ventilation tube after meticulous fluid suction. MVT was done under Zeiss Microscopy (Carl Zeiss Microscopy, GmbH, Munich, Germany). The patients were discharged on the same operative day, with oral antibiotics for 1 week, and precautions to avoid ear wetting or ear manipulation. The patients were seen in the outpatient clinic one week after surgery. Ear examination and toilet were done, and feedback was asked about hearing improvement. The patients were asked to return every 2 months till tube extrusion and healing of the tympanic membrane.

Postoperative phonological assessment

EPP assessment was performed 3 and 6 months postoperatively using the same items employed preoperatively.

Statistical methods

The data were analyzed using the Statistical Package of Social Science (SPSS) (version 28). The normality of the data was tested using the Kolmogorov–Smirnov single sample test. Numerical data were summarized as means and standard deviations. While qualitative data were described as frequencies and percentages. The comparison across time periods within treated groups was done using the Friedman test followed by the post-hock test for pairwise comparison, and comparison between groups was done using the Mann–Whitney test. Correlation was done using Spearman's correlation. A p value < 0.05 was considered statistically significant.

Results

Sixty children with persistent OME were enrolled in this study. Tympanometry was used to confirm the diagnosis; most children had a type B curve (42 patients, 70%), while the others had a type C curve (18 patients, 30%). Pure tone audiometry was performed for 20 children; it showed mild CHL in 12 patients (60%), and moderate CHL in 8 patients (40%). The preoperative mean speech discrimination score was 92 ± 3.5%. All patients underwent MVT and adenoidectomy. No intraoperative or postoperative complications were encountered. Postoperative otoscopic examination showed the presence of ventilation tubes in both ears in 46 children by the end of the 6 months follow-up. The tube was extruded from one side after 4 months in 4 patients, and after 6 months in 2 patients, while both tubes were extruded after 4 months in 3 patients, and after 6 months in 5 patients. All patients with extruded tubes showed normal intact tympanic membranes. Patients with tubes still in place were subjected to a longer follow-up period till tube extrusion. However, all children exhibited normal hearing by a familial witness, so, repeated tympanometry was not required (according to the policy of our institute).

Preoperative EPP assessment showed that 55 patients (91.7%) had phonological disorders, the mean PCC was 86.5 ± 8.1%, and the mean PDI was 0.82 ± 0.5 (Table 1).

Comparison between children with mild and moderated degrees of hearing loss with OME as regards speech discrimination, preoperative PCC, and PDI showed that there was a significantly higher average of speech discrimination in mild hearing loss compared to moderate hearing loss (94 ± 2.9 versus 89 ± 1.7 respectively, p value < 0.001). In addition, there was a significantly higher average of PCC in mild hearing loss compared to moderate hearing loss (91.6% ± 5.3% versus 78.9% ± 5.1% respectively, p value < 0.001), however, there was a significantly lower PDI in mild hearing loss compared to moderate hearing loss (0.5 ± 0.3 versus 1.3 ± 0.3 respectively, p value < 0.001) (Table 2).

Comparison of preoperative and postoperative (3 and 6 months) EPP showed a statistically significant difference between the 3 time periods regarding PCC, with an overall p value < 0.001. In addition, there was a significant increase in PCC 6 months compared to 3 months postoperatively (p value < 0.001). Regarding PDI, there was a statistically significant difference between all time periods (preoperative, 3, and 6 months postoperatively), with an overall p value < 0.001. Also, there was a significant decrease in PDI 6 months compared to 3 months after surgery (p value < 0.001) (Table 1).

Table 1 Changes in PCC and PDI across the three time periods

	Preoperative	Postop 3 months	Postop 6 months	*p* value
PCC	86.52% ± 8.1	91.4% ± 6.7	95.5% ± 5.5	< .001
PDI	.82 ± .5	.77 ± 1.5	.25 ± .3	< .001

PCC Percentage of consonants correct, *PDI* Process density index, *Preop* preoperative, *Postop* postoperative

Table 2 Association of degree of hearing loss in children with OME with speech discrimination and preoperative PCC and PDI

	Hearing loss (*N* = 20)		
	Mild (*N* = 12, 60%)	Moderate (*N* = 8, 40%)	*p* value
Speech discrimination	94 ± 2.9	89 ± 1.7	< .001
Preop PCC	91.6% ± 5.3%	78.9% ± 5.1%	< .001
Preop PDI	.5 ± .3	1.3 ± .3	< .001

Preop preoperative, *PCC* Percentage of consonants correct, *PDI* Process density index, *N* total number

Table 4 Correlation between age, speech discrimination, and postoperative PCC and PDI

		Age	Speech discrimination
Postop PCC	*r* value	.278	.832
	P value	.031	< .001
Postop PDI	*r* value	− .261	− .802
	P value	.044	< .001

r value correlation coefficient; significant *P* value < 0.05

PCC Percentage of consonants correct, *PDI* Process density index, *Postop* Postoperative

Comparison between data of typically developed children with an equivalent age to results of phonological assessment of the children with OME showed that significant difference between controls and children with OME in preoperative PCC, the mean of PCC was 98 ± 2.4 in normal children and 86.5 ± 8.1 in children with OME. Also, there was a significant difference between controls and children with OME in preoperative PDI, the mean of PDI was 0.04 ± 0.13 in normal children and 0.82 ± 0.5 in children with OME (Table 3).

Correlation between age, speech discrimination, and postoperative PCC and PDI showed that there were strong correlations between postoperative results of speech discrimination and PCC ($r = 0.802$, p value < 0.001) and PDI ($r = -0.803, < 0.001$); however, there were weak correlations between age and postoperative PCC ($r = 0.278$, p value = 0.032) and PDI ($r = -0.261$, p value = 0.044) (Table 4).

Discussion

Although OME is a widespread disease among children, it might be overlooked as it does not always cause severe symptoms. However, the diminution of hearing in the early childhood period may lead to a cascade of events that may influence the development of children's language. We carried out this study to evaluate the consequence of OME on the phonological performance of preschool children.

The current study included 60 children with persistent OME and bilateral CHL who underwent myringotomy with ventilation tube insertion (MVT). We assessed their phonological skills before and after the operation by phonological production task that included calculation of PCC and PDI through picture naming speech samples. We detected preoperative poor phonological performance in 91.7% of children with a mean PCC of 86.5 ± 8.1% and a mean PDI of 0.82 ± 0.5. Our findings are matched with the findings that had been detected previously by Thielke and Shriberg [15], they investigated speech production errors by indices which reflect PCC scores in preschool English-speaking children with OME who demonstrated lower average scores for PCC with a mean of 77.5 ± 6.5.

Table 3 Comparison between normal children and children with OME regarding PCC and PDI

	Normal	OME preoperative	*P* value
PCC	98 ± 2.4	86.5 ± 8.1	< 0.001
PDI	0.04 ± .13	0.82 ± .5	< 0.001

OME Otitis media with effusion, *PCC* Percentage of consonants correct, *PDI* Process density index

In our study, an assessment of the association of degree of hearing loss in children with OME with speech discrimination and postoperative PCC and PDI showed that a significantly higher average of speech discrimination in mild hearing loss compared to moderate hearing loss in children with OME (94 ± 2.9 versus 89 ± 1.7 respectively, p value < 0.001). In addition, there was a significantly higher average of preoperative PCC in mild hearing loss compared to moderate hearing loss, however, there was a significantly lower preoperative PDI in mild hearing loss compared to moderate hearing loss (Table 2). These results are expected because children with OME who have inconsistent auditory input in early life and problems in distinguishing minimally distinctive speech are more likely to experience phonological deficits. The hypothesis that fluctuating CHL caused by OME could disrupt speech perception and therefore phonological development was suggested previously in the literature [16].

Our study showed a statistically significant difference in phonological performance between three time periods in preschool children with OME after doing a pairwise comparison. Regarding PCC and PDI scores, the significant time periods were 3 and 6 months postoperatively versus preoperative assessment. In addition, there was a significant increase in

the mean PCC 6 months (95.5% ± 5.5) compared to 3 months (91.4% ± 6.7) postoperatively (p value < 0.001). Also, there was a significant decrease in the mean PDI 6 months (0.25 ± 0.3) compared to 3 months (0.77 ± 1.5) postoperatively (p value < 0.00). Our results indicated that treatment of OME for preschool children is important since this is the phase of language and phonological development which are dependent on the integrity of the auditory system. Maw et al. [17] evaluated language abilities in children with OME, half of their patients were treated by surgical intervention, and the other half were treated conservatively. Nine months postoperatively, the authors found significant retardation of speech comprehension and production within the un-operated group when compared with children who underwent surgical treatment.

To detect the effect of OME on speech outcomes, the results of typically developed children within the control group with an equivalent age were compared to the phonological results of the children with OME (Table 3). There was a significant difference between normal children and children with OME in PCC and PDI which indicates that children with OME were demonstrating phonological disorder before treatment. We found that children with OME achieved postoperative significant improvement of speech parameters; this supports the importance and efficacy of OME treatment for speech development.

To determine that the speech improvement was related to the treatment of OME during the period in which the phonological development may exhibit age-related changes, the correlation between phonological outcomes, speech discrimination, and age was performed (Table 4). The improvement of phonological parameters postoperatively was influenced mainly by speech discrimination's improvement rather than age, as we found strong correlations between postoperative results of speech discrimination and PCC ($r = 0.832$, p value < 0.001) and PDI ($r = -0.802$, p vlaue < 0.001); however, there were weak correlations between age and postoperative PCC ($r = 0.278$, p value = 0.032) and PDI ($r = -0.261$, p value = 0.044). As such therapy for children with OME could provide the conditions necessary to improve their speech discrimination and phonological performance.

Children in our study may receive distorted speech sound stimuli before treatment of their OME, which explains their phonological errors. After treatment, improvement of auditory speech stimuli could help in the development of intact phonological production, and enable children to make more meaningful and clarifying verbal communication. In line with our study, Burchinal et al. [18] detected that phonological errors tend to drop out in children with OME but more slowly than in normal children. This could explain why some of our children continued using some phonological errors after 6 months from treatment of their OME, so a longer follow-up and language therapy may be needed for those children to avoid communication and learning problems.

There are some limitations in this study. First, we could not perform a comparison of phonological performance between our children and another group of children with persistent OME who left without intervention for ethical considerations. Also, it should be taken into account that further longitudinal studies will be done to evaluate different outcomes of speech and phonological skills development to ensure the effect of the intervention for OME. The relatively small number of the studied children could be considered another limiting factor. A longer follow-up period may be needed for children with OME in even greater detail to assess their literacy skills during school years.

Conclusion

OME has an adverse consequence on the phonological performance of preschool children; it can affect different domains such as PCC and PDI. The findings of this study revealed that myringotomy with ventilation tube insertion for children with persistent OME and CHL could aid in the development of intact phonological skills. Therefore, counseling should be provided to inform the family that their children need to be managed on time. Also, it is important to follow up on the child's progress in language acquisition and manage any associated communicative disorders to prevent later literacy difficulties.

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Authors' contributions
AM conceived the study and was the main surgeon. AA collected the data. SO shared in the data collection and analyzed the data. FH was responsible for the phoniatric work in this study and wrote the manuscript. All authors read and approved the final version of the manuscript.

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Availability of data and materials
The datasets generated during this study are available from the corresponding author.

Declarations

Ethics approval and consent to participate
We adhered to the principles outlined in the Declaration of Helsinki. The study protocol was approved by the Research Ethics Committee of the Faculty of Medicine of Cairo University (N-126–2023). Parental informed consent was obtained for all patients.

Consent for publication
Not applicable.

Competing interests
Dr. Mosaad Abdel-Aziz is a co-author of this study and an Associate Editor for the journal. He has not been involved in handling this manuscript during the submission and review processes. The rest of the authors have no conflict of interest to declare.

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