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Protein energy malnutrition associates with different types of hearing impairments in toddlers: Anemia increases cochlear dysfunction

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ABSTRACT

Objectives: This work aimed to highlight a challenging asymptomatic problem which is early detection of hearing impairment in toddlers with protein energy malnutrition (PEM) as a neuro-cognitive effect of PEM on developing brain in relation to hemoglobin level.
Methods: 100 toddlers, aged 6–24 months, fifty with moderate/severe PEM and fifty healthy children, were included in study. Both TEOAEs and ABR testing were used to assess auditory function.
Results: Study reported an association between malnutrition and hearing impairment, 26% of cases had conductive deafness secondary to otitis media with effusion using tympanometry; 84.6% showed type B and 15.4% type C which may suggest developing or resolving otitis media. Their ABR showed 46% mild and 53% moderate impairment. 32% of PEM cases had sensory neural hearing loss and with type (A) tympanometry. Those were assessed using ABR; 58% had mild, 34% moderate and 8% profound impairment. 10% of PEM cases had mixed hearing loss with 50% type B and 50% type C tympanometry and their ABR showed moderate to profound impairment. TEOAEs latencies at different frequencies correlate negatively with hemoglobin level.
Conclusions: Toddlers with moderate/severe PEM had hearing impairments of different types and degrees. Neuro-physiological methods could be early and safe detectors of auditory disorders especially in high-risk toddlers. Anemia increases risk for auditory dysfunction.

1. Introduction

Malnutrition continues to be a major public health problem throughout the developing world. About 6% of children under age of five years are underweight for their age [1]. Thus, researchers are still concerned with the problems caused by malnutrition. It has been validated that nutritional sufficiency especially of protein, iron, choline and long-chain polyunsaturated fatty acids contributes to proper neuronal structure. Deficiency of one or more than one of these elements in the developing brain, due to malnutrition, can lead to impaired myelination, weak synaptic junctions and limited neural arborization [2,3]. According to World Health Organization, protein energy malnutrition (PEM) refers to "an imbalance between the supply of protein and energy and the body's demand for them to ensure optimal growth and function" [4]. Dietary proteins are the source of brain enzymes and neurotransmitters, notably catecholamine and serotonin. The quality of dietary proteins influences the nature and the quantities of cerebral proteins and neurotransmitters. Thus, the amino acid profile of the cerebral extra-cellular milieu is a function of the content and nature of dietary proteins [5]. Malnutrition is the consequence of a combination of inadequate intake of protein, carbohydrates, micronutrients and frequent infections [4–6].

Malnutrition affects virtually every organ system. Dietary protein is needed to provide amino acids for synthesis of body proteins and other compounds that have various functional roles. Energy is essential for all biochemical and physiologic functions in the body. Furthermore, micronutrients are essential in many metabolic functions in the body as components and cofactors in enzymatic processes. Malnourished children may have learning disabilities, be blind or partially sighted or have hearing loss. Malnutrition can impair brain development in young children, depending on its severity and when it occurs in the child's development [7]. The impact of under-nutrition on cognitive and psychosocial development as well as educational attainment is well documented [8]. Infants who suffer from any undernourished physical state whether attributable to intra-uterine growth retardation, maternal problems including mother's nutritional

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status during fetal development are at considerable risk of severe-to-profound sensorineural hearing loss very early in life [9].

Children suffering of PEM revealed significantly neurological signs including posterior column, spinocerebellar, retinal and peripheral nerve deficits. These signs increase in vitamin E deficiency states [7,10].

Hearing impairment can have a major impact on a child's development, and because early identification improves prognosis, screening programs have been widely and strongly advocated. The recommended hearing screening techniques are either otoacoustic emissions (OAE) testing or auditory brainstem evoked responses (ABR) [9,11].

2. Methods

During the period from May 2010 to November 2013, this cross sectional study included 50 infants suffered from under nutrition according to WHO, 2006 [12], and diagnosed to have protein energy malnutrition (PEM) according to Welcome's classification, 1970 [13]. Their ages ranged from six months to two years, twenty two (44%) were females and twenty eight (56%) were males recruited from Pediatric Outpatients' Clinic, Children's hospital; audiological examinations were carried out in Audiology unit, Ain Shams University, both are tertiary hospitals, Cairo, Egypt.

Fifty healthy children – sex and age matched – with patients' group were included as control. Infants had history of recurrent otitis media or family history of deafness, prematurity, and neonatal hyperbilirubinemia were excluded from the study.

After taking an informed consent from the parents of all subjects and approving the research by the hospital ethical committee, both groups were submitted to the following: thorough history taking. Complete physical examination and anthropometric measurements, including, height, weight, head circumference, mid-arm circumference and chest circumference to diagnose or exclude PEM. Anthropometric information of height-for-age *Z*-scores (HAZ) and body-mass-index-for-age *Z*-scores (BMIz) in children under the age of 5 years [12].

$$Z\text{-score (or SD-score)} = \frac{(\text{Observed value}) - (\text{Median reference value})}{\text{Standard deviation of reference population}}$$

Nutritional status of the children was staged by PEM classification using weight/weight for age ratio: it was accepted as normal those were between 90 and 110%, mild PEM those were between 75 and 89%, moderate PEM those were between 60 and 74% and severe PEM those were between those were <60% [14].

Children with mild PEM were excluded from the study because mild PEM were rarely encountered owing to the illiteracy and/or low socioeconomic standard of most of parents of those children. Due to subtle onset of PEM, variable course of the pathology, all of included toddlers have been diagnosed with PEM at least a month before inclusion in the study.

Urine analysis, renal function test and liver function tests were done to roll out systemic affection. Serum albumin level to detect hypo-albuminemia, which was diagnosed if albumin level was lower than 2.5 g/dL [15]. Depending on hemoglobin level, toddlers were divided into anemic patients with hemoglobin levels below 10 g/dL and non-anemic patients who had higher hemoglobin levels [16].

Otoscopic examination, immittancemetry including tympanometry and acoustic reflex threshold testing using Grasson Staddler impedance meter model GSI33 was performed. Transient Evoked otoacoustic emissions (TEOAEs) were obtained by using Smart Intelligent OAEs analyzer, version 3.02. Subjects were resting in a sound treated room. A probe fitted to the tested ear delivered acoustic stimuli at an average of 85 dB SPL and responses (echo levels) were recorded at 5 frequency bands over a range of 1–4.0 kHz responses. The results of TEOAEs were interpreted into one of three categories [17]: *Pass*; response was 3 dB or above in all test frequency bands; *Partial pass*; response was present in at least one of the test frequency bands; but not in all frequency bands, and *Fail*; no response is present in any of the test frequency bands.

ABR testing: All subjects were tested for threshold detection to assure normal hearing thresholds, which were one of the criteria of both groups, and to determine ABR waves indices. They were tested during normal sleep. Acoustic clicks were delivered to the tested ears via TDH39 earphone. Stimuli were manipulated in 10 dB steps until reach threshold. Latencies were calculated in traces of 80 dBnHL intensity level. Latencies of the main waves: I, III and V; were measured to document conductive from sensorineural pathology. Degrees were as follows: mild (40–50) dB, moderate to severe (50–70) dB & severe to profound 70 to >90 dB.

An IBM computer using SPSS (Statistical Program for Social Science) version 15 analyzed the data as follows: quantitative variables as mean, SD and range, qualitative variables as number and percentage. Chi-Square test X^2 was used to compare between diagnosis according to sex, Fisher exact test was performed in table containing value less than 5 and Paired *t* test was performed in comparison between parameters on 1st and 2nd observations. $P < 0.05$ was considered a significant.

3. Results

Studied patients ($n = 50$) aged between 6 and 24 months with mean age 14.9 ± 6.5 months. Twenty two (44%) were females and twenty eight (56%) were males. Anthropometric measures (Table 1) evaluated weight % for age and weight *Z*-score with a mean value in patients' group (59.5 ± 9.7) and (0.09 ± 0.99) respectively, and in controls (97.8 ± 10.8) and (0.04 ± 1) respectively. Height % for age and height *Z*-score mean values in patients group were (82.7 ± 7.6) and (0.29 ± 0.87) respectively and in controls (101 ± 2.36) and (0.33 ± 1.08) respectively. We used left mid upper arm circumference as an index of malnutrition as it reflects muscle mass and it was significantly lower in the PEM patients with a mean value (11.8 ± 0.31) cm compared to its value in controls was (12.9 ± 0.33) cm and it was statistically significant $P = 0.00$. Also, triceps skin fold thickness was statistically lower in patients (10 ± 0.06) mm compared to controls (12 ± 0.06) mm due to loss of subcutaneous fat.

Protein energy malnutrition patients showed 28% conductive deafness, 32% SNHL and 10% mixed hearing loss. Regarding conductive deafness cases (28%), were secondary to otitis media with effusion and they were tested with tympanometry for assessment of the outer and middle ear system and showed 84.6%

Table 1
Anthropometric data among patients and control.

Data	Patients Mean ± SD	Control Mean ± SD	*T* test	*P* value**
Weight % for age	59.5 ± 9.7	97.8 ± 10.8	18.513	0.00
Weight *z*-score	0.094 ± 0.99	0.045 ± 1	−0.311	0.00
Length/height % for age	82.7 ± 7.6	101 ± 2.36	16.414	0.00
Length/height z-score	0.29 ± 0.87	0.33 ± 10.8	−2.766	0.00
Weight for length/height % for age	77.9 ± 13.2	92.7 ± 7.22	−6.387	0.00
Weight for length/height *z*-score	−0.14 ± 0.14	1.1 ± 0.7	−0.6	0.00
Triceps skin fold (mm)	10 ± 0.065	12 ± 0.063	−14.396	0.00
Left mid upper arm circumference (cm)	11.8 ± 0.31	12.98 ± 0.33	−16.913	0.00
Hemoglobin (gm %)	9.51 ± 1.45	12.8 ± 1.43	−13.936	0.01

** Highly significant, $P \leq 0.01$.