

***Comparison Of Auditory Steady- State Response,
Auditory Brain Stem Response And Behavioral Test
Methods In Evaluation Of Hearing In Infants And
Children***

Thesis

*Submitted in partial fulfillment of MD degree in
Audiology*

By

Salwa Mahmoud Abd el Latif el Hadeka
M.B., B.Ch., M.Sc

Supervisors

Prof. Dr. Mohamed Tarek Ghannoum

*Professor of Audiology
Faculty of Medicine
Cairo University*

Dr. Mona Hassan Selim

*Assistant Prof. of Audiology
Faculty of Medicine
Cairo University*

Dr. Amira Maged El Shennawy

*Assistant Prof. of Audiology
Faculty of Medicine
Cairo University*

*Faculty of Medicine
Cairo University
2010*

بسم الله الرحمن الرحيم

" قالوا سبحانك لا علم لنا الا ما علمتنا انك أنت العليم الحكيم "

صدق الله العظيم
الآيه ٣٢ سورة

البقرة

To
My Family

Acknowledgment

First and above all thanks to **God**, the most merciful and who is behind all success.

I would like to express my all sincere and deepest gratitude to **Prof. Dr. MOHAMED TAREK GHANNOUM**, Professor of Audiology, Faculty of Medicine, Cairo University, for his kind supervision, helpful advice and giving much of his precious time and constant support throughout the conduction of this work.

I wish to thank **A. Prof. Dr. MONA HASSAN SELIM**, Assistant Professor of Audiology, Faculty of Medicine, Cairo University, for her generous assistance, kind cooperation and valuable advice throughout this work.

I am most grateful to **A. PROF. Dr. AMIRA MAGED EL SHENNAWY**, Assistant Professor of Audiology, Faculty of Medicine, Cairo University, for her continuous efforts, great help, and advices to make this work at its best.

My deepest thanks for my professors and colleagues of Audiology unit of Hearing and Speech Institute, Cairo University for their continuous support.

Salwa Mahmoud, 2010

Abstract

The most widely used auditory evoked potential (AEP), is auditory evoked brain stem response (ABR). Another AEP is the auditory steady state response (ASSR). ASSR allows for frequency specific threshold determination. **Objective:** To study the results of ABR, ASSR and behavioral tests in infants and young children and to determine the best methods for accurate detection of hearing loss in this age group. **Methods:** A total number of 60 infants and children were examined. Their age range was 7 months to 8 years and they were of both sexes. They were all subjected to the following tests; basic audiologic evaluation according to age group, ABR for threshold detection and ASSR with carrier frequencies 250, 500, 1000, 2000 and 4000 Hz. **Results:** There was a significant difference between PTA and ASSR thresholds at all frequencies among the tested groups. The difference decreases in severe and profound hearing losses (HLs). There was a statistically significant correlation between PTA and ASSR at different frequencies. There was a significant difference between ABR thresholds and average threshold of PTA (1000, 2000 and 4000 Hz). Statistical analysis of the correlations between ABR thresholds and average PTA thresholds (1000, 2000, and 4000 Hz) revealed a significant correlation in cases of moderate to profound HLs. There was a significant difference between ABR thresholds and average threshold of ASSR (1000, 2000 and 4000 Hz). Statistical analysis of the correlation between ABR thresholds and ASSR thresholds (1000, 2000 and 4000 Hz) showed a significant correlation in cases of mild, moderately severe, severe and profound HLs. No significant difference was found between young and older children as regards ASSR and ABR thresholds. There was a significant difference in the amplitude of ASSR response between young and older children at 1000 Hz in minimal HL and at 250 Hz in mild and moderately severe HLs. ASSR response amplitude increased with increasing intensity. At severe and profound hearing losses, the amplitude tends to be smaller as compared to normal and other milder degrees of HLs which is obvious at 2000 and 4000 Hz. **Conclusion:** ASSR cannot reliably differentiate between normal ears and those with mild hearing loss and the accuracy of the results improves with severe to profound sensorineural hearing losses. The best ASSR frequencies to correlate with PTA were 1000, 2000 and 4000 Hz. ABR thresholds were best correlated with the average of PTA and ASSR (1000, 2000 and 4000 Hz) in severe and profound hearing losses. At higher

degrees of HL, the slope of ASSR amplitude intensity curves tends to decrease.

Recommendation of this study is to use a test battery which includes behavioral tests, ABR and ASSR for accurate evaluation and management of hearing loss in infants and young children. Further research on the ASSR amplitude intensity relationship for its possible application in suggesting the presence of recruitment and hence its application in hearing aid fitting.

Keywords:

Auditory steady state evoked response, Auditory evoked brain stem response, Pure tone audiometry, Children, Hearing loss.

CONTENTS

	<u>Page</u>
1. INTRODUCTION& RATIONALE.....	1
2. AIM OF THE WORK.....	3
3. REVIEW OF LITERATURE.....	4
<i>a)Detection and assessment of hearing loss in infants and children.....</i>	4
<i>b)Auditory evoked brain stem response.....</i>	7
<i>c) Auditory steady state response.....</i>	10
<i>d)Variables affecting ASSR.....</i>	44
<i>e)The multiple auditory steady–state evoked response (MASTER) technique.....</i>	50
<i>f)Auditory steady–state evoked response in infants and children.....</i>	56
<i>g) Comparing ASSR, ABR and behavioral hearing tests.....</i>	59
4. SUBJECTS & METHODS.....	61
5. RESULTS	70
6. DISCUSSION.....	125
7. CONCLUSION	139
8. RECOMMENDATIONS	140
9. SUMMARY	141
10. REFERENCES	145
11. ARABIC SUMMARY	1

Abbreviations

- ABR:** Auditory brain stem response
- AM:** Amplitude modulation
- AM²:** Exponential modulation envelopes
- AMFR:** Amplitude modulated following response
- ASSR:** Auditory steady-state evoked response
- BOA:** Behavioral observation audiometry
- CF:** Carrier frequency
- CM:** Cochlear microphonic
- CPA:** Conditioned play audiometry
- dB:** Decibel
- deg:** Degree
- EEG:** Electro-encephalogram
- EFR:** Envelope following response
- EOAEs:** Evoked otoacoustic emissions
- EPs:** Evoked potentials
- f:** Frequency
- FFT:** Fast Fourier Transform
- FM:** Frequency modulation
- gr:** Group
- HL:** Hearing level

Hz: Hertz

IAFM: Independent amplitude and frequency modulation

JCIH: Joint Committee on Infant Hearing

KHz: Kilo Hertz

MASTER: Multiple auditory steady-state evoked response

MF: Modulating frequency

min: Minute

MLAEP: Middle latency auditory evoked potential

MM: Mixed modulation amplitude and frequency

ms: Millisecond

nHL: Normal hearing level

NV: Nano volt

PTA: Pure tone audiometry

rms: Root mean square

SAM: Sinusoidally amplitude modulated tone

sec: Second

SIN³: Sinusoidally amplitude modulated tone with exponential envelope

SN-10: Slow negative response after 10 seconds

SPL: Sound pressure level

SSEP: Steady state evoked potential

UV: Micro volt

VRA: Visual reinforcement audiometry

List of tables

Page

Table (1): Gender distribution of the groups	72
Table (2): Mean, standard deviation and range of age in years in the groups under study	73
Table (3): Mean and standard deviation of hearing threshold level of PTA and ASSR at different frequencies in group 1	75
Table (4): Mean and standard deviation of hearing threshold level of PTA and ASSR at different frequencies in group 2	76
Table (5): Mean and standard deviation of hearing threshold level of PTA and ASSR at different frequencies in group 3	77
Table (6): Mean and standard deviation of hearing threshold level of PTA and ASSR at different frequencies in group 4	78
Table (7): Mean and standard deviation of hearing threshold level of PTA and ASSR at different frequencies in group 5	79
Table (8): Mean and standard deviation of hearing threshold level of PTA and ASSR at different frequencies in group 6	80
Table (9): Mean and standard deviation of hearing threshold level of PTA and ASSR at different frequencies in group 7	81
Table (10): Mean difference in threshold between PTA and ASSR at different frequencies in the study groups	82
Table (11): Mean, SD and range of difference in threshold between PTA and ASSR at different frequencies in group 1	84
Table (12): Mean, SD and range of difference in threshold between PTA and ASSR at different frequencies in group 2	84
Table (13): Mean, SD and range of difference in threshold between PTA and ASSR at different frequencies in group 3	85

Table (14): Mean, SD and range of difference in threshold between PTA and ASSR at different frequencies in group 4	85
Table (15): Mean, SD and range of difference in threshold between PTA and ASSR at different frequencies in group 5	86
Table (16): Mean, SD and range of difference in threshold between PTA and ASSR at different frequencies in group 6	86
Table (17): Mean, SD and range of difference in threshold between PTA and ASSR at different frequencies in group 7	87
Table (18): The Pearson correlation coefficient between PTA threshold and ASSR threshold at different frequencies in group 1	93
Table (19): The Pearson correlation coefficient between PTA threshold and ASSR threshold at different frequencies in group 2	93
Table (20): The Pearson correlation coefficient between PTA threshold and ASSR threshold at different frequencies in group 3	94
Table (21): The Pearson correlation coefficient between PTA threshold and ASSR threshold at different frequencies in group 4	94
Table (22): The Pearson correlation coefficient between PTA threshold and ASSR threshold at different frequencies in group 5	95
Table (23): The Pearson correlation coefficient between PTA threshold and ASSR threshold at different frequencies in group 6	95
Table (24): The Pearson correlation coefficient between PTA threshold and ASSR threshold at different frequencies in group 7	96
Table (25): Mean and standard deviation of hearing threshold level of ABR and PTA average (1000, 2000 and 4000 Hz) in the tested groups	103
Table (26): Mean difference in threshold between PTA average (1000, 2000 and 4000 Hz) and ABR in the study groups	104

Table (27): Mean, SD and range of difference in threshold between PTA average (1000, 2000 and 4000 Hz) and ABR in the tested groups	105
Table (28): The Pearson correlation coefficient between ABR threshold and mean PTA threshold (1000, 2000 and 4000 Hz) in the 7 groups	106
Table (29): Mean and standard deviation of hearing threshold of ABR and ASSR average (1000, 2000 and 4000 Hz) in the tested groups	107
Table (30): Mean difference in threshold between ASSR average (1000, 2000 and 4000 Hz) and ABR in the study groups	108
Table (31): Mean, SD and range of difference in threshold between ASSR average (1000, 2000 and 4000 Hz) and ABR in the tested groups	109
Table (32): The Pearson correlation coefficient between ABR threshold and average ASSR threshold (1000, 2000 and 4000 Hz) in the 7 groups	110
Table (33): Mean difference in ASSR threshold at different frequencies between young and older children in the tested groups	112
Table (34): Mean difference in ABR threshold between young and older children in the tested groups	113
Table (35): Mean and standard deviation of ASSR amplitude at different frequencies between young and older children in group 1	113
Table (36): Mean and standard deviation of ASSR amplitude at different frequencies between young and older children in group 2	114

Table (37): Mean and standard deviation of ASSR amplitude at different frequencies between young and older children in group 3	114
Table (38): Mean and standard deviation of ASSR amplitude at different frequencies between young and older children in group 4	115
Table (39): Mean and standard deviation of ASSR amplitude at different frequencies between young and older children in group 5	115
Table (40): Mean and standard deviation of ASSR amplitude at different frequencies between young and older children in group 6	116
Table (41): Mean and standard deviation of ASSR amplitude at different frequencies between young and older children in group 7	116
Table (42): The mean and standard deviation of ASSR amplitude at the different intensities in the tested frequencies in group 1	118
Table (43): The mean and standard deviation of ASSR amplitude at the different intensities in the tested frequencies in group 2	119
Table (44): The mean and standard deviation of ASSR amplitude at the different intensities in the tested frequencies in group 3	120
Table (45): The mean and standard deviation of ASSR amplitude at the different intensities in the tested frequencies in group 4	121
Table (46): The mean and standard deviation of ASSR amplitude at the different intensities in the tested frequencies in group 5	122
Table (47): The mean and standard deviation of ASSR amplitude at the different intensities in the tested frequencies in group 6	123
Table (48): The mean and standard deviation of ASSR amplitude at the different intensities in the tested frequencies in group 7	124

List of figures

	<i>Page</i>
Figure (1): ABR threshold trace	9
Figure (2): Stimuli used to evoke the ASSR	11
Figure (3): The EEG response	12
Figure (4): Different stimuli used in audiologic evaluation	14
Figure (5): Transient and steady state stimuli	15
Figure (6): Neural generators of ASSR	18
Figure (7): Normal hearing PTA thresholds compared to ASSR thresholds	21
Figure (8): Profound hearing loss PTA thresholds compared to ASSR thresholds	21
Figure (9): Different stimuli used in ASSR	31
Figure (10): Recording and analysis of auditory steady state responses	35
Figure (11a): Graphical analysis of ASSR (supra-threshold stimuli)	37
Figure (11b): Graphical analysis of ASSR (sub-threshold stimuli)	38
Figure (12): Apparent latency calculation	40
Figure (13): Signals in noise	41
Figure (14): Weighted averaging in ASSR	43
Figure (15): Prediction of behavioral thresholds using regression analysis	49
Figure (16): Testing auditory steady state responses	51
Figure (17): Testing MASTER response in one ear stimulation	51
Figure (18): Testing MASTER responses when two ears are stimulated	52

Figure (19): Testing MASTER responses to four frequency stimuli	53
Figure (20): Threshold estimation using multiple steady state responses	54
Figure (21a): Monaural ASSR stimulation	64
Figure (21b): Binaural ASSR stimulation	65
Figure (22a): Test screen of ASSR polar plot response	67
Figure (22b): Test screen of ASSR color plot response	67
Figure (23): Mean hearing threshold level of PTA and ASSR at different frequencies in group 1	75
Figure (24): Mean hearing threshold level of PTA and ASSR at different frequencies in group 2	76
Figure (25): Mean hearing threshold level of PTA and ASSR at different frequencies in group 3	77
Figure (26): Mean hearing threshold level of PTA and ASSR at different frequencies in group 4	78
Figure (27): Mean hearing threshold level of PTA and ASSR at different frequencies in group 5	79
Figure (28): Mean hearing threshold level of PTA and ASSR at different frequencies in group 6	80
Figure (29): Mean hearing threshold level of PTA and ASSR at different frequencies in group 7	81
Figure (30): Mean difference in threshold between PTA and ASSR at 250 Hz in the tested groups	88
Figure (31): Mean difference in threshold between PTA and ASSR at 500 Hz in the tested groups	89
Figure (32): Mean difference in threshold between PTA and ASSR at 1000 Hz in the tested groups	90