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Original Article

Frequency Amplitude Ratio of Ocular Vestibular Evoked Myogenic Potential in Different Age Groups

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BACKGROUND: High levels of sound intensity can be detected by the vestibular system. It is a clinical method used to assess the vestibular system's response to sound stimulation. In healthy individuals, research has indicated that the use of low-frequency stimuli results in decreased vestibular evoked myogenic potential (VEMP) thresholds, especially a 500 Hz tone-burst. As people age, their frequency tuning changes, moving towards higher frequencies.

METHODS: Eighty healthy participants participated in this cross-sectional investigation. Both air conduction (AC) and bone conduction (BC) were used as stimulation methods in the ocular VEMP (oVEMP) test. The following oVEMP parameters were assessed in the study: the inter-frequency peak amplitude ratio (FAR). Furthermore, a rectified FAR (Frequency Amplitude Ratio)—a technique that normalizes the VEMP response amplitude according to the strength of muscle contraction as determined by EMG (Electromyogram) —was examined.

RESULTS: Statistically significant differences in FAR and rFAR (rectified Frequency Amplitude Ratio) of oVEMP were observed among the 5 age groups when using both AC and BC stimuli.

CONCLUSION: This study used both AC and BC stimuli to determine age norms for the FAR (1000/500 Hz) of oVEMP. When compared to younger age groups, participants over 50 had much greater FAR and corrected FAR values. Comparable FAR results were obtained from both AC and BC stimuli, suggesting that either approach can be utilized for testing.

KEYWORDS: Ocular VEMP, frequency amplitude ratio, bone conduction, frequency tuning

INTRODUCTION

Sound is recognized not just by the cochlea but also by the vestibular system when exposed to high sound levels. Stimulation of the vestibular system through acoustic means can trigger the production of vestibular evoked myogenic potentials (VEMPs).[1] The vestibular evoked myogenic potential is generated by muscle responses triggered by loud sounds. There are 2 types of VEMP: Cervical VEMP (cVEMP)[2] and ocular VEMP (oVEMP) described a decade after the cVEMP.[3] Cervical VEMP activates the saccule, the inferior vestibular nerve, and the descending vestibulo-spinal pathways.[4] The occurrence of the biphasic P13-N23 wave in cervical recordings validates the operation of the saccule.[5] The utricle, the superior vestibular nerve, and the ascending vestibular pathways all produce oVEMP. The presence of a biphasic N10-P15 wave during ocular VEMP is necessary for the utricular reflex to be reliable, and it is impacted by the kind of stimulus employed as well as the muscle activity (inferior oblique muscles) that causes eye movement.[6]

In healthy people, the VEMP amplitudes in both ears are comparatively symmetrical.[7] However, in healthy individuals, aging has an impact on the Interaural Amplitude Asymmetry Ratio.

In individuals with good health, VEMP responses exhibit greater sensitivity to lower frequencies. Compared to other frequencies, a tone burst at 500 Hz can result in faster response rates, lower thresholds, and larger amplitudes for both oVEMP and cVEMP. Frequency tuning is affected by age, leading to a shift toward higher frequencies.[8]

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Rationale

There have been no studies conducted in thus far that evaluate the frequency amplitude tuning characteristics of oVEMP across various age groups, regardless of whether air conduction (AC) or bone conduction (BC) stimulation is utilized.

Aim of the Study

In order to establish normative data relevant to various age groups, this study uses stimuli at 500 and 1000 Hz through both AC and BC methods to assess age-related variations in oVEMP parameters, specifically the Inter-Frequency-amplitude ratio (FAR) (frequency tuning).

METHODS

Subjects

In this cross-sectional study, 80 healthy, normal people without a history of illnesses or problems with their ears, hearing, or balance participated. After gaining their consent to participate in the study, participants will be chosen from among individuals undergoing the preoccupation assessment at Kasr Al-Aini Cairo University Hospital Audiology Clinic, as well as volunteers from the clinic's medical staff and healthy relatives of patients. The Cairo University Research Ethics Committee gave its ethical approval to this study. (Code: MS-328-2022, date: 16/9/2022). An informed consent was obtained and documented in patients records after explaining the procedure and whether any side effects would occur which are minimal.

Inclusion Criteria

Normal, healthy people of all sexes, both young and old divided into the following age groups: 20-29 years, 30-39 years, 40-49 years, 50-59 years, and ≥ 60 years.

MAIN POINTS

- This study included 80 normal healthy individuals divided into 5 groups. Each participant in the study was subjected to ocular vestibular evoked myogenic potential (oVEMP).
- This study aims to obtain normative data of oVEMP by air conduction (AC) and bone conduction (BC) at frequencies 500-1000 Hz in different age groups. It also aims to evaluate the effect of aging on VEMP parameters and frequency tuning and their correlation with age.
- In this study oVEMP AC and BC are more commonly elicited at 500 Hz than at 1000 Hz.
- Participants in the 50-59 years age group had a significantly larger mean of rectified Frequency Amplitude Ratio (FAR) and FAR than those in the 20-29 years age group using AC and BC. As age increased, FAR and rectified FAR of cervical VEMP (cVEMP) and oVEMP in both ears increased using AC, but the rectified FAR of cVEMP and oVEMP increased only in the left ear using BC.
- This study provided norms for FAR (1000/500 Hz) of oVEMP using AC and BC stimuli in different age groups. There were no statistically significant differences between AC and BC FAR oVEMP in either ear in any of the 5 studied groups.
- Aging influences VEMP frequency tuning especially above 50 years old. So, it is recommended that every laboratory should have its own normative data for each age group, with VEMP normalization to decrease variability among individuals.

Exclusion Criteria

- Conductive hearing loss.
- External auditory canal anomalies.
- History of surgery in one or both ears.
- Vestibular disorders.
- Patient's history of a brain tumor, e.g., vestibular schwannoma
- Third nerve palsy.
- Anatomical abnormalities in facial or neck muscles.

Each participant in the study will be subjected to

1. Full history taking.
2. Audiologic evaluation:

a) Pure tone audiometry:

Pure-tone BC thresholds will be obtained at 500 Hz, 1 kHz, 2 kHz, and 4 kHz.

Pure-tone AC thresholds obtained from 250 Hz to 8 kHz, and

b) Speech reception threshold and word recognition score.

c) Tympanometry with 226-Hz probe-tone.

3. Vestibular Evoked Myogenic Potentials testing.

Ocular Vestibular Evoked Myogenic Potential

- Electrode Montage

After cleansing the skin with a cleaning gel, the recording of neuroelectrical activity was conducted using closely positioned snap electrodes on the surface located below the eyes: the positive electrode was positioned on the orbital margin beneath the center of the eye, and the reference electrode was placed roughly 15-30 mm below on the cheek with the ground electrode positioned on the forehead. The impedance of the electrodes was maintained below 5 kΩ. The test was carried out with the participants seated upright and instructed to relax their facial muscles and gaze upward with their eyes only, without moving their head.

- Stimulus and Recording Parameters

Tone bursts at 2 different frequencies (500 Hz and 1000 Hz) that would be used as stimuli were used. A clinical bone vibrator (B71) will be used to provide bone-conducted stimuli, while ER-3A insert earphones will be used to deliver air-conducted stimuli. The intensity of the monoaural presentation will be 100 dB nHL for AC and 60 dB nHL for BC. The rising time, fall time, and plateau length are set at 1 ms, 1 ms, and 2 ms, respectively. Five hertz was chosen as the stimulation rate. A filter set to 1-1000 Hz was used to gather at least 200 sweeps. A 50 ms time span was allotted for analysis. To guarantee reproducibility, 2 averaged signal trials were collected. The presence or absence of VEMP responses was determined by detecting the N10-p15 biphasic response. The following parameters were recorded in the preserved oVEMP response:

The Ocular Vestibular Evoked Myogenic Potential Parameters That Will Be Assessed Are:

- P10 latency, N15 latency, and P10-N15 peak to peak amplitude, and inter-aural amplitude asymmetry (difference) ratio at 500 Hz.

- P10 latency, N15 latency, and P10-N15 peak to peak amplitude, and inter-aural amplitude asymmetry (difference) ratio at 1000 Hz.
- Calculating the oVEMP FAR between 500 Hz and 1000 Hz in the same ear (1000 Hz/500 Hz FPA).
- Calculating the oVEMP inter-FAR between 500 Hz and 1000 Hz in the same ear (1000 Hz/500 Hz FPA).
- Equipment.

1. Sound treated room (Amplisilence Model E).
2. Two channel audiometer: Itera II (IVladsen Corporation, USA), calibrated according ISO standards. TDH-39 headphones and a Radioear B71 bone vibrator were used.
3. Tympanometry: Zodiac 901 (Madsen Corporation, USA), calibrated according ISO standards.
4. Evoked potentials system: Neuro-Audio (Neurosoft Ltd, Russia).

Statistical Analysis Methods and Technique

SPSS version 21 (IBM SPSS Corp.; Armonk, NY, USA) will be used for data analysis. Whereas the mean, standard deviation, median, and interquartile range will be used to demonstrate quantitative data, numbers and percentages will be used to represent qualitative data. Accordingly, significant parametric and non-parametric tests (the Mc Nemar, Student's *t*, and chi-square tests) will be conducted. At $P \leq .05$, the significance level was set.

Sample Size

Conducting an analytical investigation with a study power of 0.80 and an alpha error of 0.05 using the Clincalc sample size calculator to determine the smallest sample size needed to see how age and stimulus type affect the ocular VEMPs' frequency tuning and amplitude asymmetry ratio. Eighty patients make up the estimated sample size.

Table 1. Mean, Standard Deviation, and Range of Age in Years of the Study Groups

	Age			
	Mean	SD	Min.	Max.
Group 1	23.31	2.60	20	29
Group 2	35.44	2.97	31	39
Group 3	43.88	2.75	40	48
Group 4	52.06	2.69	50	59
Group 5	68.56	8.16	60	85

RESULTS

The research consisted of 80 healthy adult participants: 40 were male and 40 were female, with an average age of 44. 65 years ± 15. 97 (spanning from 20 to 85 years). Participants were classified into 5 categories based on age:

Group 1 (20-29 years), Group 2 (30-39 years), Group 3 (40-49 years), Group 4 (50-59 years), and Group 5 (above 60 years).

All individuals involved in this research exhibited bilateral type A tympanograms indicating normal middle ear pressure. Table 1 presents the Mean (X), standard deviation (SD), and age range in years of the study groups.

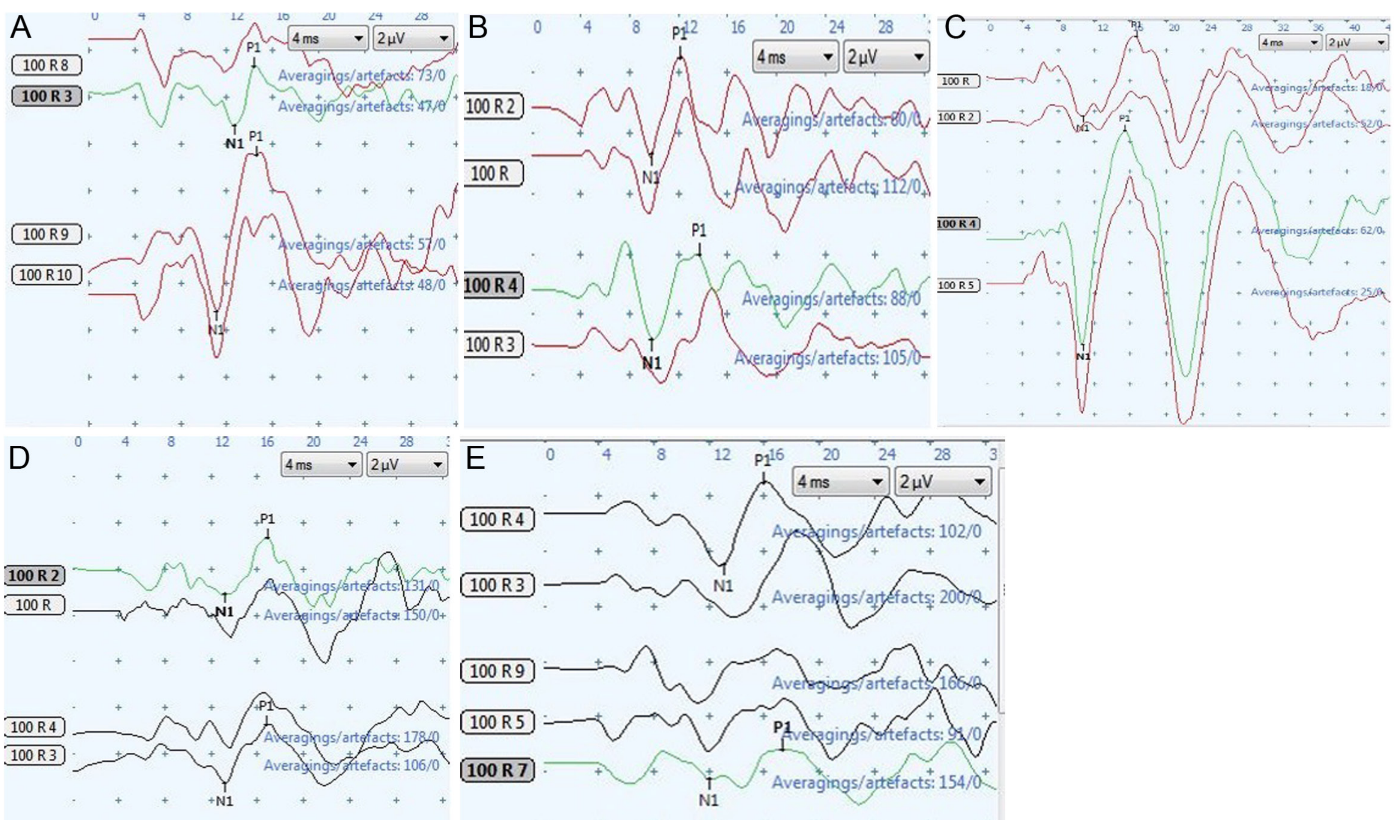

Figure 1. oVEMP Air conduction (AC) traces at 1000 Hz and 500 Hz in the 5 age groups. (A) Group 1 oVEMP AC, (B) Group 2 oVEMP AC, (C) Group 3 oVEMP AC, (D) Group 4 oVEMP AC, and (E) Group 5 oVEMP AC.

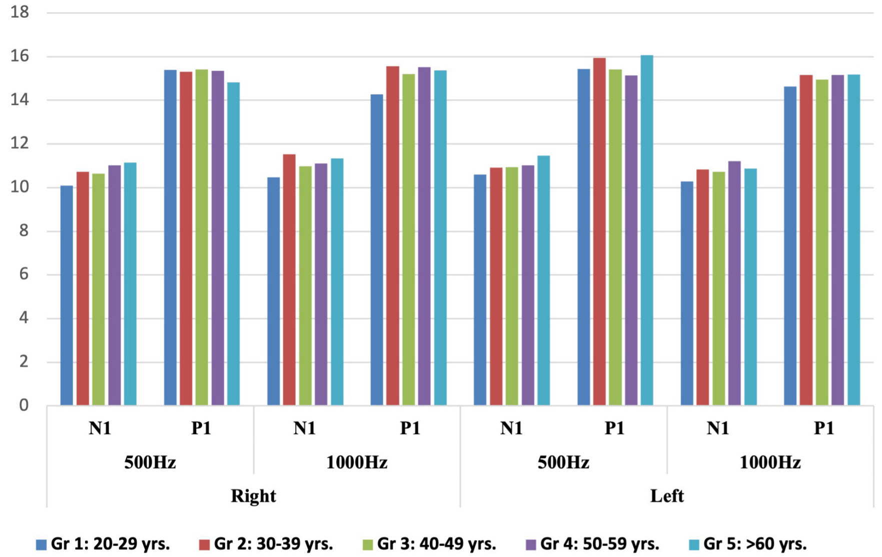

Figure 2. oVEMP Air Conduction P1 and N1 Latencies at 500 and 1000 Hz of the right and left ears of the 5 age groups in this study.

There were considerable disparities among the 5 age groups concerning N1 latency at 500 Hz, N1 latency and P1 latency at 1000 Hz, as well as amplitude (P1-N1) at 500 Hz of right oVEMP AC. There were no statistically significant differences among the 5 age groups with respect to all parameters of LT oVEMP AC, except for amplitude at 500 Hz (Figures 1-4).

Across all 5 age groups in this investigation, no statistically significant variations in oVEMP AC FAR or corrected FAR were seen between the right and left ears ($P > .05$) (Figure 5).

There existed notable disparities among the 5 age groups in terms of N1 latency, as well as amplitude at 500 Hz for right oVEMP BC. There existed notable disparities among the 5 age groups in terms of N1 latency and amplitude at both 500 Hz and 1000 Hz for LT oVEMP BC (Figure 6-9).

Regarding oVEMP BC FAR or corrected FAR, no statistically significant differences were found between the right and left ears in any of the study's 5 age groups ($P > .05$) (Figure 10).

With the exception of the left ear in group 2, none of the 5 age groups showed statistically significant variations between the AC and BC of oVEMP in response to FAR in either ear. (Table 2). This is because the left ears in the 30-39 years age group exhibited a significantly larger (0.7) B. C - rFAR oVEMP compared to the right ears (0.58) ($P = -2.698$; $P = .0173$). Nevertheless, with respect to the rFAR, no significant differences were found (Table 3).

Age and N1 delay at 500 Hz in both ears were directly correlated in a statistically significant ($P < .05$) way. Age and the amplitude at 500 Hz in both ears showed a statistically significant ($P < .05$) adverse relationship. In both ears, the relationship between age and FAR and rFAR was statistically significant ($P < .05$). Age and P1 delay at 1000 Hz in the right only were directly correlated in a statistically significant ($P < .05$) way (Table 4).

Age and N1 delay at 500 Hz in both ears and N1 latency at 1000 Hz in the left ear were directly correlated in a statistically significant ($P < .05$) way. Age and amplitude at 500 Hz in both ears, amplitude at

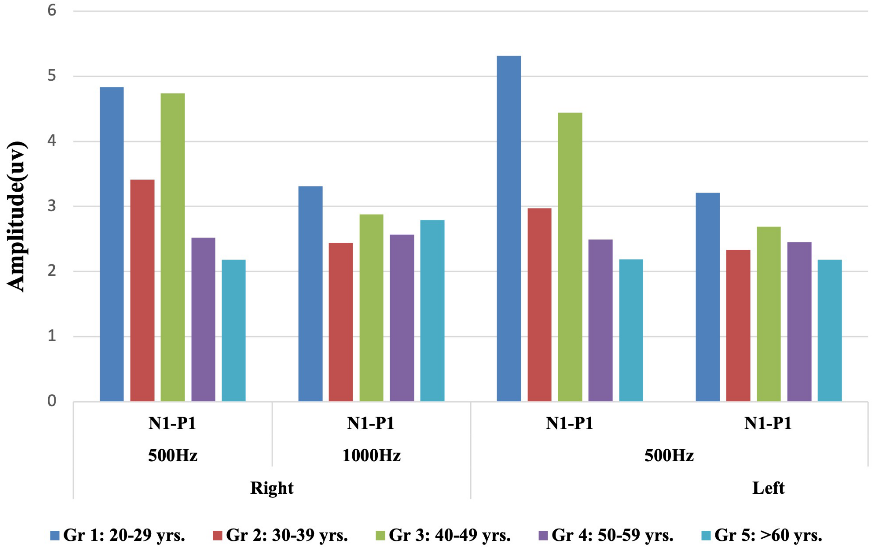

Figure 3. oVEMP Air Conduction P1-N1 amplitude at 500 and 1000 Hz of the right and left ears of the 5 age groups in this study.

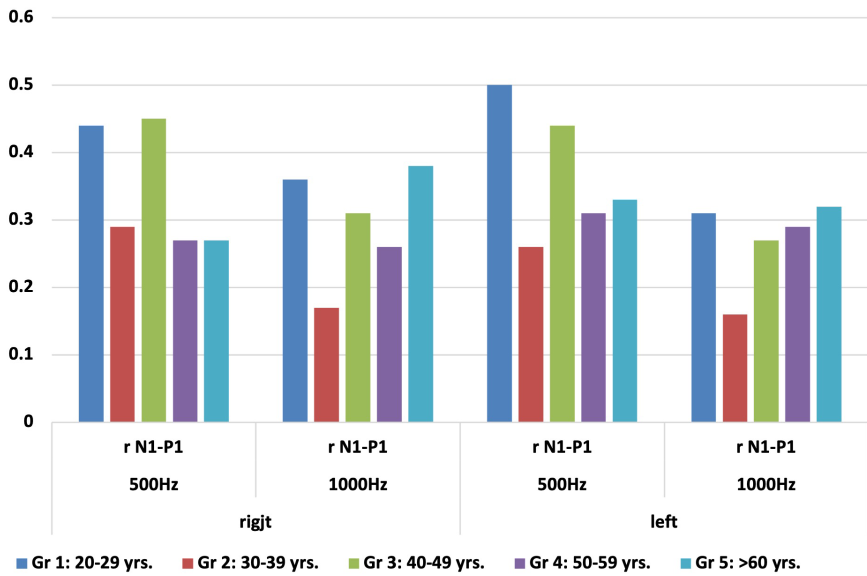

Figure 4. oVEMP Air Conduction rectified (N1-P1) amplitude at 500 and 1000 Hz of the right and left ears of the 5 age groups in this study.

1000 Hz in the left ear, and age and rectified amplitude in the left ear at 500 Hz all showed statistically significant ($P < .05$) inverse correlations. Age and FAR in both ears, age and rFAR in the left ear, and age and r IAAR% were all directly correlated in a statistically significant ($P < .05$) way (Table 5).

DISCUSSION

Using 500 and 1000 Hz and AC and BC stimuli, this study aimed to assess age-related changes in oVEMP parameters, specifically Inter-FAR (frequency tuning), and ascertain whether there was a difference in frequency tuning between AC and BC stimulation of oVEMP.

According to this study, 500 Hz is more frequently used to trigger oVEMP AC and BC than 1000 Hz. In contrast to 70 (87%) and 60 (75%) at 1000 Hz using AC and BC, respectively, oVEMPs were induced at 500 Hz in 71 (89%) and 76 (90%) using these methods.

Fu et al[9] demonstrated that the ideal stimulus frequency for oVEMP is 500 Hz or 1000 Hz, which is consistent with the findings. Most subjects still displayed the optimal frequency around 500 Hz, even though some middle-aged people had the best frequency at 1000 Hz.

Frequency Amplitude Ratio of Ocular Vestibular Evoked Myogenic Potential Using Air Conduction and Bone Conduction Stimuli

Tone bursts are superior to clicks for producing oVEMPs.[10] The maximum oVEMP was recorded in response to AC tone bursts between 500 and 1000 Hz.[11]

This study provided criteria for the FAR (1000/500 Hz) of oVEMP using AC and BC stimuli in different age groups. Since the FAR or corrected FAR oVEMP with either AC or BC stimuli did not differ statistically significantly between the right and left ears in any of the 5 age groups in this study, the right ear values are displayed here ($P > .05$).

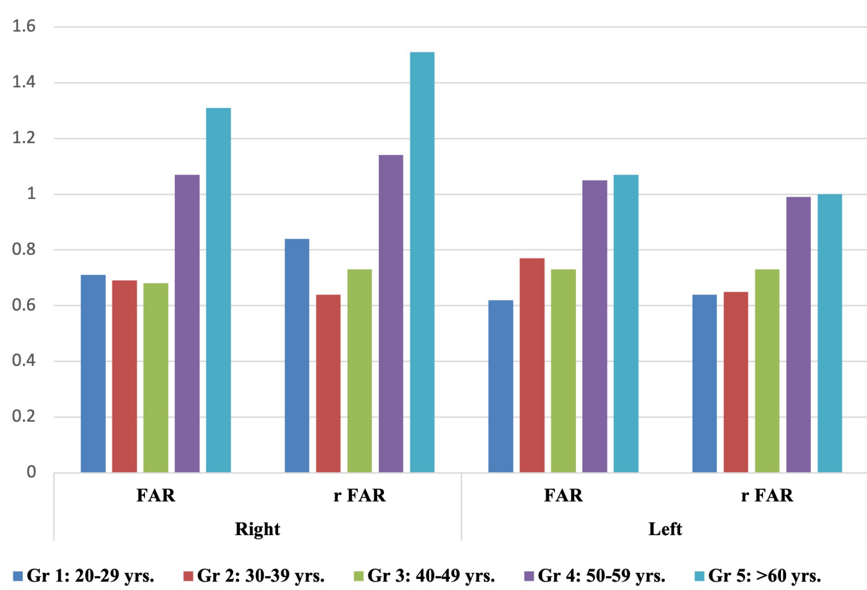

Figure 5. oVEMP Air Conduction FAR and rFAR of the right and left ears of the 5 age groups in this study.

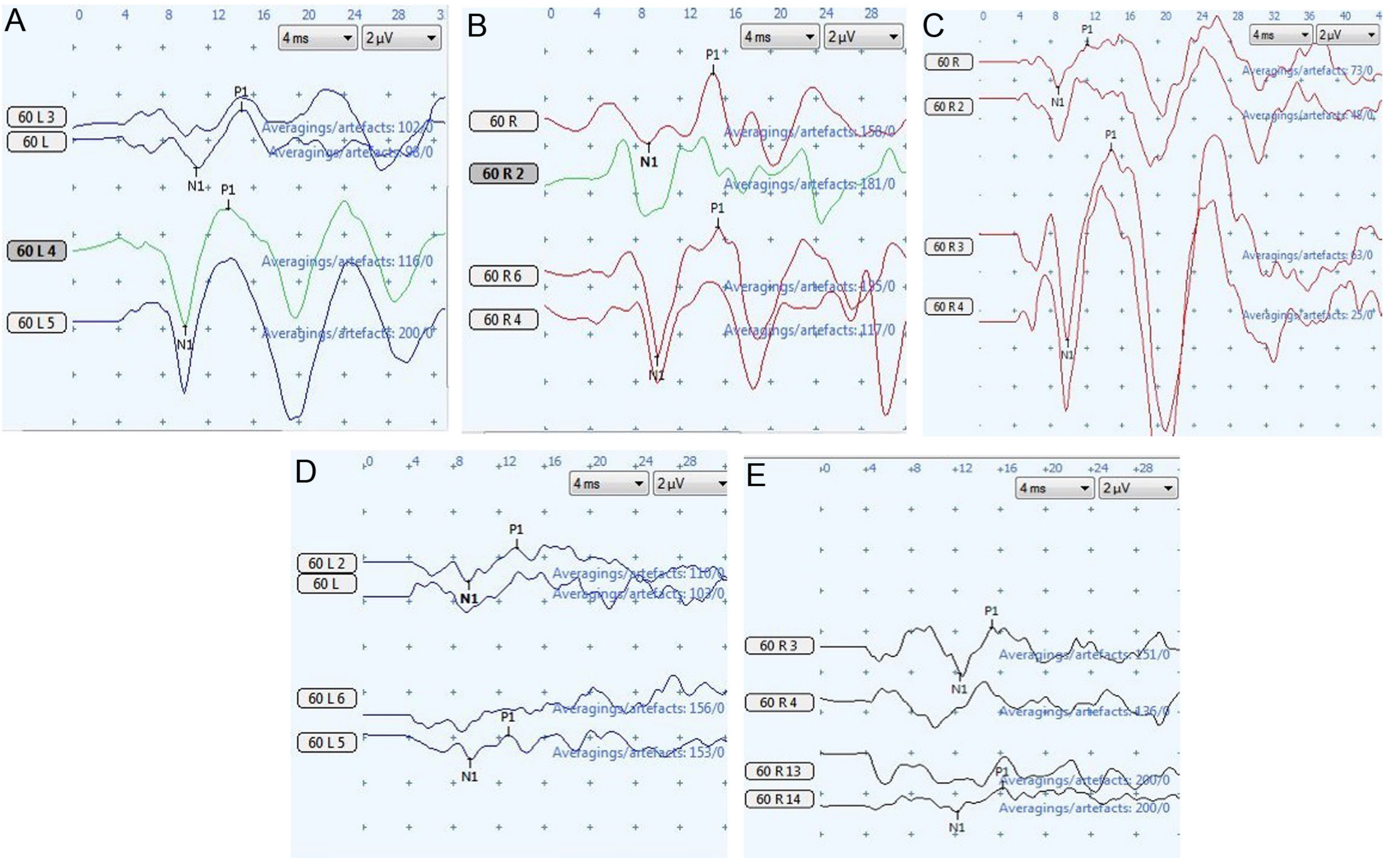

Figure 6. oVEMP Bone conduction (BC) traces at 1000 Hz and 500 Hz in the 5 age groups. (A) Group 1 oVEMP BC, (B) Group 2 oVEMP BC, (C) Group 3 oVEMP BC, (D) Group 4 oVEMP BC, and (E) Group 5 oVEMP BC.

- Air Conduction

The FAR values rose with age in the current study, which used AC stimuli to rectify the FAR of oVEMP. The normal subjects' FAR values ranged from approximately 0.69-0.98 for subjects aged 20-29, 0.44-0.84 for those aged 30-39, 0.55 to 0.90 for those aged 40-49, 0.85 to 1.43 for those aged 50-59, and 0.89 to 2.12 for those aged >60 (and).

- Age on oVEMP AC FAR

Compared to individuals in the 20-49 age group, those over 60 displayed much higher FAR and corrected FAR (Tables 2 and 2). The FAR and corrected FAR of oVEMP AC in both ears rose with age.

Singh et al[12] discovered that the ≥60 age group had a considerably higher IFAR than the age groups up to 49. Additionally, compared to all other age groups up to 39 years old, the IFAR in the 50-59 age group was noticeably higher. The older adults' oVEMP tuning

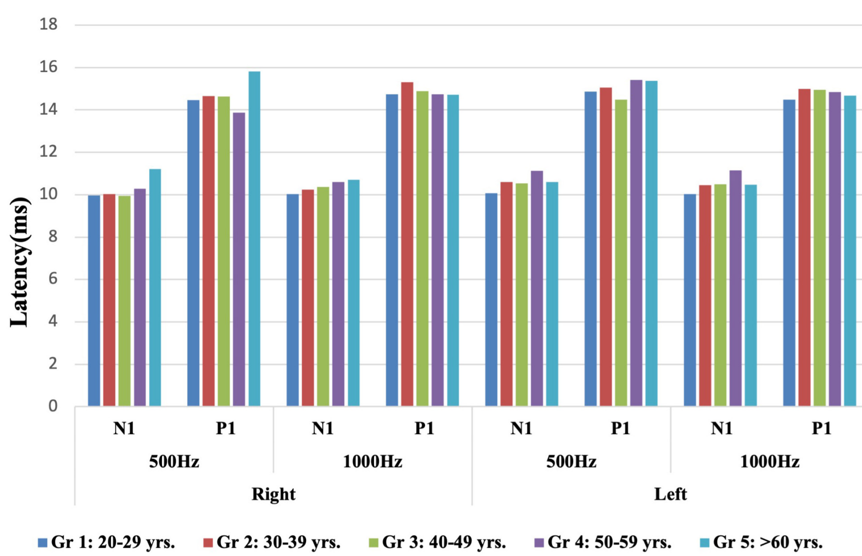

Figure 7. oVEMP Bone Conduction P1 and N1 Latencies at 500 and 1000 Hz of the right and left ears of the 5 age groups in this study.

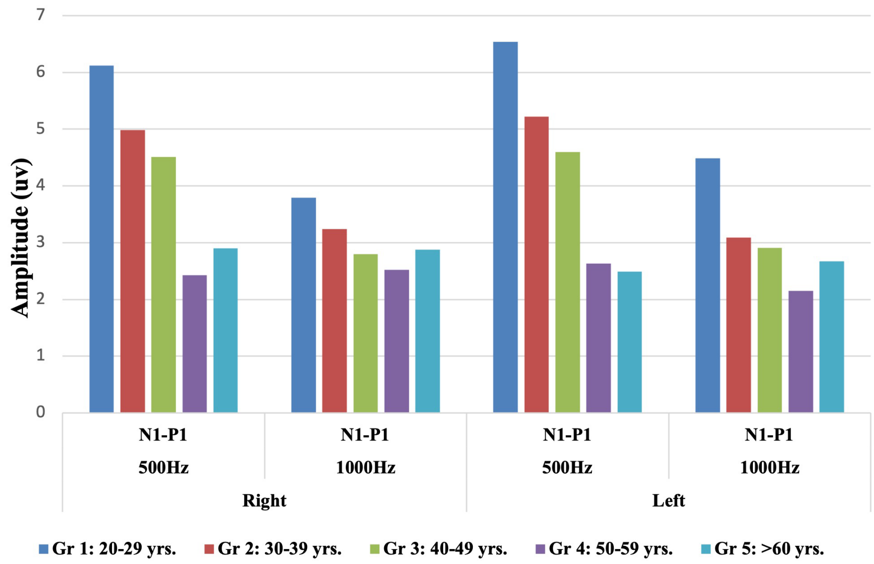

Figure 8. oVEMP Bone Conduction P1-N1 amplitude at 500 and 1000 Hz of the right and left ears of the 5 age groups in this study.

seemed to shift to a higher frequency when compared to the young adult group.

As people age, the ideal stimulus frequency to produce a VEMP may alter. As a result, not all age groups may respond well to 500 Hz as the frequency for eliciting VEMPs.[8] Singh and Firdose[13] found that frequency tuning of the oVEMP at 1000 Hz was significantly more prevalent among people over 60. Since the shift in frequency tuning to ≥1000 Hz is frequently used to identify Meniere's disease, it is advised that age-related adjustment be employed for the diagnosis of Meniere's illness when using frequency tuning of oVEMP. For instance, the effects of aging must be taken into account when using IFAR to diagnose Meniere's illness.[14]

- Bone Conduction

The FAR values rose with age in the current study's rectified FAR of oVEMP using BC stimuli: the normal subjects' FAR values ranged from roughly 0.47 to 0.90 for subjects aged 20-29, 0.56 to 0.98 for subjects aged 30-39, 0.43 to 1.16 for subjects aged 40-49, 0.70 to 1.09 for subjects aged 50-59, and 0.40 to 1.12 for normal subjects aged >60 (Tables 2 and 2).

- Age on oVEMP BC FAR

Individuals in the 50-60 years age range displayed a substantially higher corrected FAR than those in the 30-39 years age range (Tables 2 and 2). But in certain of the study's ears, the ≥60 age group displayed a lower FAR than the 50-59 age group. This is explained by the study's smaller sample size, and most participants in the ≥60 age group had absent waves, which impacted the mean amplitude. Additionally, the corrected FAR grew solely in the left ear, while the FAR of oVEMP BC increased in both ears as age increased (Tables 2 and 2).

The right hemisphere has been thought to age more quickly than the left.[15] Therefore, the left ear will be more influenced than the right by the oVEMP crossed reflex. Due to aging, the left ear's FAR may be larger than the right. The left ears will change significantly because of this.

According to Singh et al[12], who assessed oVEMPs for tone-bursts at 500 Hz and 1000 Hz from 270 healthy persons divided into 6 age groups, the ≥60 years age group showed a significantly greater IFAR

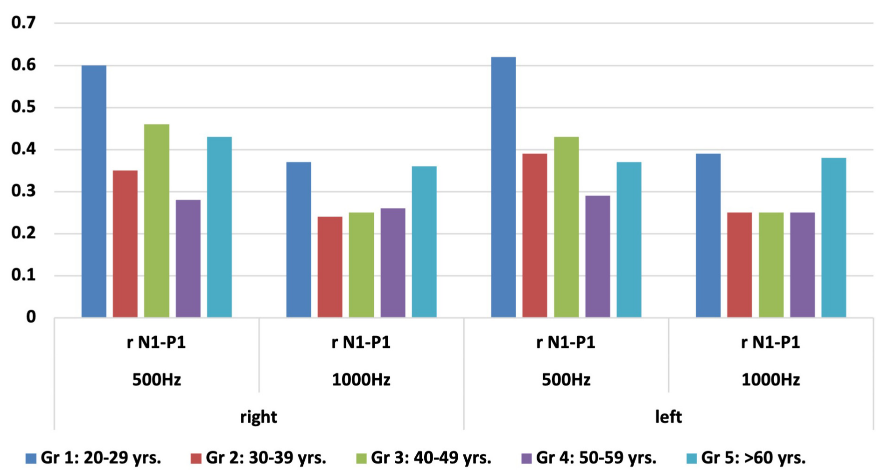

Figure 9. oVEMP Bone Conduction rectified (N1-P1) amplitude at 500 and 1000 Hz of the right and left ears of the 5 age groups in this study.

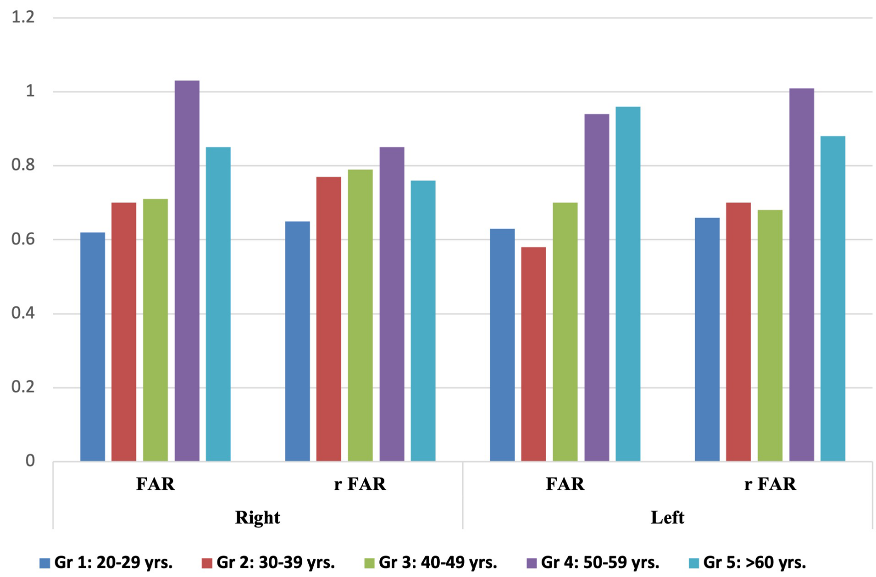

Figure 10. oVEMP Bone Conduction FAR and rFAR of the right and left ears of the 5 age groups in this study.

than the age groups up to 49 years. This finding is consistent with the results. Furthermore, the IFAR in the 50-59 age group was significantly greater than that of all other age groups up to 39.

Singh and Barman,[14] found that, for the frequency pairs of 750/500, 1000/500, and 1500/500, but not for tuned frequency/500, there was a substantial positive connection between participants' age and FAR in healthy persons. A weak positive association was also observed between the variables. However, only people under 50 were allowed to participate in the study. The authors concluded that when utilizing IFAR to diagnose Meniere's disease, the impact of aging must be considered. Singh and Firdose,[13] revealed that among older persons over 60, frequency tuning of the oVEMP at 1000 Hz was substantially more common. Age-related adjustment is recommended for Meniere's

Table 2. Comparison Between Air Conduction and Bone Conduction, oVEMP FAR, in the Right and Left Ears of the Studied Groups

oVEMP FAR					*t*	*p*
	Age Group		AC	BC		
Right	Group 1: 20-29 years	Mean	0.71	0.62	−0.637	534
		SD	0.22	0.45		
	Group 2: 30-39 years	Mean	0.69	0.7	0.099	923
		SD	0.11	0.19		
	Group 3: 40-49 years	Mean	0.68	0.71	−0.118	908
		SD	0.55	0.4		
	Group 4: 50-59 years	Mean	1.07	1.03	−0.466	654
		SD	0.42	0.34		
	Group 5: >60 years	Mean	1.31	0.85	0.373	728
		SD	0.57	0.25		
Left	Group 1: 20-29 years	Mean	0.62	0.63	−0.224	826
		SD	0.18	0.14		
	Group 2: 30-39 years	Mean	0.77	0.58	−5.275	000*
		SD	0.15	0.13		
	Group 3: 40-49 years	Mean	0.73	0.7	−1.276	224
		SD	0.42	0.29		
	Group 4: 50-59 years	Mean	1.05	0.94	−1.131	291
		SD	0.3	0.4		
	Group 5: >60 years	Mean	1.07	0.96	0.373	728
		SD	0.51	0.3		

Table 3. Comparison Between Air Conduction and Bone Conduction, oVEMP Rectified FAR, in the Right and left Ears of the Studied Groups

oVEMP - r FAR					*t*	*p*
	Age Group		AC	BC		
Right	Group 1: 20-29 years	Mean	0.84	0.65	−1.737	.1042
		SD	0.27	0.31		
	Group 2: 30-39 years	Mean	0.64	0.77	1.030	.3219
		SD	0.34	0.40		
	Group 3: 40-49 years	Mean	0.73	0.79	0.512	.6175
		SD	0.31	0.66		
	Group 4: 50-59 years	Mean	1.14	0.85	−1.210	.2610
		SD	0.50	0.34		
	Group 5: >60 years	Mean	1.51	0.76	−0.977	.3840
		SD	0.81	0.29		
Left	Group 1: 20-29 years	Mean	0.64	0.66	−0.0633	.9505
		SD	0.21	0.33		
	Group 2: 30-39 years	Mean	0.65	0.70	0.483	.6379
		SD	0.23	0.35		
	Group 3: 40-49 years	Mean	0.73	0.68	−0.938	.3656
		SD	0.41	0.44		
	Group 4: 50-59 years	Mean	0.99	1.01	0.109	.9160
		SD	0.30	0.51		
	Group 5: >60 years	Mean	1.00	0.88	0.0593	.9556
		SD	0.37	0.36		

Table 4. Correlation Age and AC oVEMP Parameters at 500 and 1000 Hz in the Right and Left Ears of the Study Participants

oVEMP Air Conduction				Age	
				r	*P*
Right	500 Hz	Latency (ms)	N1	0.305	.010*
			P1	−0.101	.403
		Amplitude (uv)	P1-N1	−0.376	.001*
			r P1-N1	−0.169	.159
	1000 Hz	Latency (ms)	N1	0.210	.086
			P1	0.342	.004*
		Amplitude (uv)	P1-N1	−0.126	.305
			r P1-N1	−0.023	.851
	FAR 1000/500 Hz			0.431	.000*
	rect FAR 1000/500 Hz			0.394	.001*
Left	500 Hz	Latency (ms)	N1	0.290	.014*
			P1	0.017	.890
		Amplitude (uv)	P1-N1	−0.362	.002*
			r P1-N1	−0.147	.220
	1000 Hz	Latency (ms)	N1	0.215	.078
			P1	0.130	.291
		Amplitude (uv)	P1-N1	−0.214	.080
			r P-N1	0.045	.714
	FAR 1000/500 Hz			0.409	.001*
	rect FAR 1000/500 Hz			0.378	.002*
IAAR% at 500 Hz				0.064	.596
rect IAAR% at 500 Hz				0.199	.096
IAAR% at 1000 Hz				−0.133	.279
rect IAAR% at 1000 Hz				0.075	.545

*Significantly different.

Table 5. Correlation Age and BC oVEMP Parameters at 500 and 1000 Hz in the Right and Left Ears of the Study Participants

oVEMP Bone Conduction				Age	
				r	*P*
Right	500 Hz	Latency (ms)	N1	0.340	.003*
			P1	0.164	.160
		Amplitude (uv)	P1-N1	−0.504	.000*
			r P1-N1	−0.157	.179
	1000 Hz	Latency (ms)	N1	0.226	.078
			P1	−0.012	.928
		Amplitude (uv)	P1-N1	−0.240	.060
			r P1-N1	−0.071	.581
	FAR 1000/500 Hz			0.321	.012*
	rect FAR 1000/500 Hz			0.185	.153
Left	500 Hz	Latency (ms)	N1	0.235	.043*
			P1	0.132	.257
		Amplitude (uv)	P1-N1	−0.542	.000*
			r P1-N1	−0.260	.024*
	1000 Hz	Latency (ms)	N1	0.361	.005*
			P1	0.101	.441
		Amplitude (uv)	P1-N1	−0.370	.004*
			r P1-N1	−0.052	.693
	FAR 1000/500 Hz			0.511	.000*
	rect FAR 1000/500 Hz			0.311	.016*
IAAR% at 500 Hz				0.126	.280
rect IAAR% at 500 Hz				−0.063	.590
IAAR% at 1000 Hz				−0.298	.025*
rect IAAR% at 1000 Hz				−0.024	.857

*Significantly different.

disease diagnosis when employing frequency tuning of oVEMP since the change in frequency tuning to ≥1000 Hz is commonly used for Meniere's disease identification.

Fu et al[9] examined the impact of tone burst frequency of 250, 500, 1000, and 1500 Hz on Asian participants' oVEMP waveforms. For cVEMP, the ideal frequency was either 500 Hz or 1000 Hz. Todd et al[16] demonstrated that the optimal frequency range was 400-800 Hz, with the biggest response occurring at 100 Hz. One particular utricular aspect might be the optimal frequency of 100 Hz.

Air Conduction Versus Bone Conduction—Ocular Vestibular Evoked Myogenic Potential Frequency Peak Amplitude Ratio

The AC and BC of oVEMP FAR or corrected FAR in either ear did not differ statistically significantly in any of the 5 age groups. As a result, both AC and BC stimulation produced comparable FAR values and are suitable for testing.

Lin et al[17] discovered that the ideal BC-oVEMP parameter is an input stimulation setting of 500 Hz and 45 dB. In clinical practice, 500 Hz is advised as the major AC-oVEMP stimulus frequency since it is BC-oVEMP. Since the thresholds of irregular utricular neurons for ACS decrease from 500 to 1500 Hz, it is prudent to attempt 750 or 1000 Hz if a satisfactory response is not obtained at 500 Hz.[18]

Miyamoto et al[19] reported that the B-VEMP's frequency response may be influenced by the utricle's frequency response. Despite numerous research on the saccule, frequency dynamics on the utricle have never been documented to date.

Todd et al[16] demonstrated that BC cVEMPs have peak sensitivity at lower frequencies than for AC stimuli, which is in contrast to the research. The frequency tuning of AC oVEMP and BC oVEMP was shown to be different by Donnellan et al.[20] The tuning peak of AC oVEMP is approximately 1000 Hz, in contrast to the tuning peak of bone-conducted oVEMP, which is approximately 400 Hz.[20]

Frequency tuning of oVEMP for BC stimuli is lower than for AC stimulation.[21] The difference in the tuning frequencies between AC stimulation and BC vibration might be explained by differences in the vestibular regions activated.[20]

Håkansson et al[22] claimed that the B71 output's limitations prevented a complete definition of frequency tuning for BC. More thorough research of frequency and impulsive effects has been made possible by more potent bone vibrators that have wider frequency responses than audiometric bone vibrators.

CONCLUSION

1. The percentage of VEMP response loss was found to increase with age above 50 years, and greatly above 60 years of age, including those above 70 years. Therefore, laboratory-specific normative data should be applied for each age group when interpreting results. Additionally, VEMP data might not be as useful for diagnosis in the senior population.
2. The oVEMP is more frequently induced by AC or BC at 500 Hz as opposed to 1000 Hz.
3. Age criteria for the FAR of oVEMP (1000/500 Hz) were established in this investigation using AC and BC stimuli. Participants over 50 showed significantly higher FAR and adjusted FAR in oVEMP compared to the younger age groups. Because they yielded similar FAR results, both AC and BC stimuli can be used in testing.

Age effects should be taken into consideration when using oVEMP. So, each laboratory should establish its own norms for each set of stimulus parameters at different age groups.

Data Availability Statement: The data that support the findings of this study are available on request from the corresponding author.

Ethics Committee Approval: This study was approved by the Ethics Committee of Cairo University (Approval no.: MS-328-2022; Date: September 16, 2022).

Informed Consent: Written informed consent was obtained from the patients/patient who agreed to take part in the study.

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