Evaluation of audiovestibular function in patients exposed to extracorporeal shock wave lithotripsy

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Background and aim
The noise given off by the extracorporeal shock wave lithotripsy (ESWL) device during treatment may put hearing and vestibular system at risk. Therefore, this study attempts to explore the effect of the noise generated by the ESWL device on hearing and vestibular systems of patients receiving such a method of management.

Patients and methods
Thirty patients (60 ears), who were candidates for management by ESWL were examined. Each patient of this study underwent the following: (a) basic audiological evaluation including: pure-tone audiometry, speech audiometry, and middle ear immittance measurement; (b) transient evoked otoacoustic emissions; (c) vestibular evaluation: videonystagmography.

Results
There was increase in pure-tone thresholds of both ears in the post-ESWL as compared to pre-ESWL sessions at high frequencies (2–4 kHz). There was a statistically significant difference between response level in dBSPL of both ears at pre-ESWL and post-ESWL sessions at frequencies (2, 3, and 4 kHz). Two (6.7%) patients in the study developed unilateral weakness in the post-ESWL sessions. There was a significant difference in positioning and positional tests between pre-ESWL and post-ESWL sessions.

Keywords:
auditory, extracorporeal shock wave lithotripsy, vestibular

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Introduction

Extracorporeal shock wave lithotripsy (ESWL) is frequently used in urology to break stones. The noise given off by the ESWL device during treatment may put hearing at risk [1].

Several studies determined that temporary tinnitus and diminution of hearing occurred after ESWL treatment, depending on the period and intensity of noise. This effect is due to the temporary disorder in outer hair cells [2].

The anatomical proximity between the vestibular labyrinth and the cochlea, both have a common arterial blood supply and hair cell ultrastructure. This point to the possibility of vestibular damage associated with noise-induced hearing loss (NIHL) [3].

This study attempted to explore the effect of the noise generated by the ESWL device on hearing and vestibular systems of patients receiving such method of management.

Patients and methods

Thirty patients (60 ears), who were candidates for management by ESWL for the first time in Urology Department in Assiut University Hospitals, were enrolled in this study. Their age ranged from 15 to 50 years.

They were selected according to the following criteria:
(1) Bilateral normal hearing prior to exposure to ESWL (proved by pure tone audiometry [PTA])
(2) All patients had no history of middle ear disorders (proved by tympanometry and acoustic reflex)
(3) All patients had no history suggestive of inner ear diseases
(4) No history of systemic diseases affecting the hearing acuity and vestibular system
(5) No history of ototoxic drug intake or previous exposure to risky noise.

Informed consent was obtained from all participants in the study, and the study was approved by Ethical Committee, Faculty of Medicine, Assiut University, Egypt.

Equipment

(1) ESWL with an electromagnetic type (Dornier, Germany)
(2) Dual channel clinical audiometer (Madsen model Orbiter 922, GN Otometrics, Cobenhagen, Dennmark)
(3) Immitancemeter (Impedance audiometer, Interacoustics AZ 26, Dennmark)
(4) Double room sound treated both (IAC 1602A-t; Industrial Acoustic Company, Miami, Florida, USA)
(5) Intelligent Hearing System (otoacoustic emissions).
(6) Otometrics VNG (GN Otometrics Demo Facility, Madsen model, Cobenhagen, Dennmark)
(7) Sound level meter (Bruel and Kjaer 2235).

Methods

Each patient was subjected to the following:
(1) Detailed history taking
(2) Abdominal radiographs (two sided) and kidney, ureter, bladder urinary ultrasonographic evaluations were obtained for all patients to diagnose urinary lithiasis. ESWL was applied with an electromagnetic type (Dornier) to all patients. Each ESWL session lasted between 20 and 40 min.

Before application of the study, noise was measured using the sound level meter, the greatest level of noise exposure was found to be at the head of the patient, with an average reading of 90 dB. The readings at the lithotripter technician's station averaged 85 dB. The anesthetist and urologist were exposed to average sound levels of 81 and 79 dB, respectively.
(1) Otological examination
(2) Basic audiologic evaluation: pure-tone audiometry, air conduction threshold in the frequency range 250–8000 Hz, and bone conduction in frequency range 500–4000 Hz.

Speech audiometry: including Arabic speech reception threshold using Arabic spondee words (Soliman, 1985) and word discrimination score using Arabic Phonetically Balanced Words (Soliman, 1976) at most comfortable level for each ear separately.

Middle ear immittance measurement including tympanometry (to evaluate middle ear function) and acoustic reflex thresholds of frequencies (500–4000 Hz).

Otoacoustic emissions

They were elicited using click stimuli and intensity was adjusted to be ~85 dBSPL.

Transient evoked otoacoustic emissions (TEOAEs) were analyzed during the 20 ms after the stimulus and a total of 260 averages on each of two buffers (A and B) were stored for analysis.

The software of computer determines amplitude of the TEOAEs in five frequency bands (1, 1.5, 2, 3, and 4 kHz).

Vestibular evaluation

Videonystagmography

Essentially after the glasses were wear and proper calibration was done, VNG consists of three parts:
(1) Oculomotor function: gaze, fixation, saccade (accuracy, latencies, and velocities), tracking (pursuit) (gain, phase, acceleration), and optokinetics (gain, phase) were evaluated
(2) Positioning and positional tests were done
(3) Caloric test: the patient was placed on supine position with head elevated 30° from the horizontal plane, in order to make the horizontal canal vertical and cold caloric stimulation was done at 30°C, proper mental tasks were given and nystagmus was recorded. The abnormalities of low-frequency horizontal canal function, asymmetry of reaction, and unilateral weakness were calculated according to the formula of Jongkees [4]. Fixation suppression during caloric test was also observed.

All basic audiological evaluation, TEOAEs and VNG were done on the following schedule:
(1) Before ESWL exposure
(2) Immediately after ESWL exposure
(3) 2 months after ESWL exposure.

Results

This study involved 30 patients who had urinary stones, their ages ranged from 15 to 50 years with a mean ± SD 33.8 ± 10.2 years and their sex distribution was 21 (70%) males and nine (30%) females. They were exposed to ESWL. Their performance in hearing and vestibular tests was done pre-ESWL, post-ESWL, and follow-up after 2 months.

There were 23 patients exposed to one ESWL session and the remaining seven patients were exposed to two sessions. Mean duration of exposure to ESWL session was 28.8 ± 6.9 min with a range of 20–40 min for each session.

Audiological test results

Pure-tone audiometry

There was a significant increase ($P < 0.05$) in pure-tone thresholds of both ears in the post-ESWL as compared with pre-ESWL sessions at frequencies 2000 and 4000 Hz.

There was no statistically significant increase ($P > 0.05$) in pure-tone thresholds of both ears in the pre-ESWL as compared to 2 months follow-up at all frequencies.

There was a statistically significant increase ($P < 0.05$) in pure-tone thresholds of both ears in the post-ESWL as compared to 2 months follow-up at frequencies 2000 and 4000 Hz.

Speech audiometry

All study patients had bilateral excellent speech discrimination scores (88–100%) proportional to the pure-tone thresholds.

Results of immitancemetry

Immittance measurements showed that all patients in the study had bilateral (type A) tympanogram and the acoustic reflexes were present at expected sensation level when elicited contralaterally at 500, 1000, 2000, and 4000 Hz in both ears.

Transient evoked otoacoustic emissions results

There was a statistically significant difference between response level in dBSPL of both ears at pre-ESWL and post-ESWL sessions at frequencies 2000, 3000, and 4000 Hz.

There was no statistically significant difference between response level in dBSPL of both ears at pre-ESWL and 2 months follow-up at all frequencies.

There was a statistically significant difference between response level in dBSPL of both ears at post-ESWL sessions and 2 months follow-up at frequencies 2000, 3000, and 4000 Hz.

Vestibular test results (videonystagmography)

Peripheral vestibular nystagmus is characterized by: unidirectional with the fast phase opposite the lesion and inhibited by visual fixation. According to Alexander's law, the nystagmus associated with peripheral lesions becomes more pronounced with gaze toward the side of the fast-beating component [5].

There was a statistically significant difference in positioning and positional tests between pre-ESWL and post-ESWL sessions.

There was a statistically significant difference ($P < 0.05$) between post-ESWL and 2 months follow-up regarding positioning and positional tests. But there was not a statistically significant difference ($P > 0.05$) regarding posthead shaking test.

Two patients in the study group developed unilateral weakness in the post-ESWL sessions with no statistically significant difference between pre-ESWL and post-ESWL sessions.

There was a significant increase in pure-tone thresholds in the right and left ears at high frequencies in patients exposed to two ESWL sessions as compared with those exposed to one session.

There was a significant correlation between TEOAEs and two ESWL sessions in the right and left ears at high frequencies, but there was no correlation between TEOAEs and one ESWL session in the right and left ears.

There was a statistically significant correlation between age and pre-ESWL PTA at frequencies 250, 500, and 1000 Hz.

There was a statistically significant correlation between age and post-ESWL PTA at frequencies 250, 1000, 4000, and 8000 Hz.

There was a statistically significant correlation between age and PTA after 2 months follow up at frequencies 250, 500, and 1000 Hz.

There was no correlation between age and TEOAEs at all frequencies.

There was no correlation between age and abnormalities in VNG test results.

Discussion

Noise is a common hazard that leads to one of the most common complaints in the adult population seen by the audiologist NIHL. The cause and effect relationship between noise exposure and hearing loss has been appreciated for many years [6].

The present study showed that noise emitted from ESWL (90 dB) may cause hearing impairment. The study involved 30 patients who had urinary stones, their ages ranged from 15 to 50 years with a mean ± SD 33.8 ± 10.2 years. They were exposed to ESWL. Their performance in hearing and vestibular tests was done pre-ESWL, post-ESWL, and follow-up after 2 months.

Basic audiological evaluation

There was a significant elevation in hearing threshold in both ears at frequencies (2 and 4 kHz) after exposure to ESWL. After 2 months, hearing threshold returned to the pre-ESWL values (temporary threshold shift) (Tables 1–3).

In the present study, all patients who developed audiometric threshold shift had bilateral affection. This similarity in hearing loss in both ears is one of the main features of NIHL. In agreement with Bakr *et al*. [7] who found that most of their study patients had bilateral hearing loss (82%) while few cases had unilateral hearing loss (18%). Although it is not uncommon to find cases with asymmetrical hearing loss. For example, McBride and Williams [8] found a 4 kHz notch in the left ear with a 6 kHz notch in the right ear in patients exposed to high impulse noise.

In contrast, Niskar *et al.* [9] reported that 85% of patients with noise-induced threshold shift have affection in one ear. Dieroff [10] explained this asymmetric hearing loss and stated that slight changes in orientation of the head relative to the noise source might cause differences in sound pressure at the ear and beyond. Job *et al.* [11] explained this asymmetry to that each ear had different intrinsic characteristics and one cochlea might be less sensitive than the other.

The results of the present study were in agreement with those recorded by Naguib *et al.* [2] and Dawson *et al.* [12], who reported temporary loss of hearing occurred after ESWL treatment. It has been emphasized that this effect is due to the temporary disorder in outer hair cells.

All patients of the present study had bilateral excellent speech discrimination scores, as the noise affects small

Table 1 Average pure-tone thresholds of the right and left ears in pre-extracorporeal shock wave lithotripsy and post-extracorporeal shock wave lithotripsy sessions

PTA	Right				*P*	Left				*P*
	Pre-ESWL		Post-ESWL			Pre-ESWL		Post-ESWL		
	Mean	SD	Mean	SD		Mean	SD	Mean	SD	
250 Hz	15.43	5.82	16.00	5.63	0.678	15.17	5.65	16.50	5.11	0.327
500 Hz	15.17	5.49	16.33	5.71	0.388	13.83	5.52	16.0	4.03	0.088
1000 Hz	13.17	4.45	15.33	4.54	0.067	14.17	4.75	14.83	5.00	0.583
2000 Hz	16.50	3.97	18.83	4.49	0.037*	13.17	3.07	17.50	4.31	0.000**
4000 Hz	15.83	4.56	19.0	3.57	0.004**	14.83	4.04	18.00	3.37	0.002**
8000 Hz	18.00	4.84	18.83	4.86	0.480	17.83	5.52	18.83	4.49	0.416

ESWL, extracorporeal shock wave lithotripsy. *Statistically significant correlation (P<0.05). **Statistically significant correlation (P<0.01).

Table 2 Average pure-tone thresholds of the right and left ears in pre-extracorporeal shock wave lithotripsy and 2 months follow-up

PTA	Right				*P*	Left				*P*
	Pre-ESWL		Follow up			Pre-ESWL		Follow up		
	Mean	SD	Mean	SD		Mean	SD	Mean	SD	
250 Hz	15.17	5.65	15.67	5.98	0.647	15.17	5.65	15.83	5.58	0.647
500 Hz	13.83	5.52	15.50	5.47	0.723	13.83	5.52	14.33	5.37	0.723
1000 Hz	14.17	4.75	13.67	4.34	0.672	14.17	4.75	14.67	4.34	0.672
2000 Hz	13.17	3.07	16.83	4.04	0.539	13.17	3.07	13.67	3.20	0.539
4000 Hz	14.83	4.04	16.33	4.34	0.629	14.83	4.04	15.33	3.92	0.629
8000 Hz	17.83	5.52	18.83	4.68	0.624	17.83	5.52	18.50	4.94	0.624

ESWL, extracorporeal shock wave lithotripsy.

Table 3 Average pure-tone thresholds of the right and left ears in post-extracorporeal shock wave lithotripsy and 2 months follow-up

PTA	Right				*P*	Left				*P*
	Post-ESWL		Follow up			Post-ESWL		Follow up		
	Mean	SD	Mean	SD		Mean	SD	Mean	SD	
250 Hz	16.00	5.63	15.67	5.98	0.825	16.50	5.111	15.83	5.584	0.631
500 Hz	16.33	5.71	15.50	5.47	0.566	16.00	4.026	14.33	5.371	0.179
1000 Hz	15.33	4.54	13.67	4.34	0.151	14.83	4.997	14.67	4.342	0.891
2000 Hz	18.83	4.49	16.83	4.04	0.042*	17.50	4.305	13.67	3.198	0.001**
4000 Hz	19.00	3.57	16.33	4.34	0.012*	18.00	3.373	15.33	3.925	0.007**
8000 Hz	18.83	4.86	18.83	4.68	0.998	18.83	4.488	18.50	4.939	0.785

ESWL, extracorporeal shock wave lithotripsy. *Statistically significant correlation (P<0.05). **Statistically significant correlation (P<0.01).

area of high frequencies and the speech range of frequencies lies between 300 and 3000 Hz [13].

Otoacoustic emissions test results

TEOAE test result to detect the possible effects of ESWL on hearing function. Because of its marked sensitivity, the TEOAE to detect subtle changes in cochlear function performed to patients of the study [13].

In the present study, there was a temporary decrease at 2, 3, and 4 kHz frequencies immediate after ESWL exposure (Tables 4–6). Our results were in accordance with those reported by Naguib *et al.* [2] who performed one session ESWL in 33 patients and multiple sessions in the remaining 12 patients. They showed that ESWL cause a temporary loss of hearing status, which seems to be related to the frequency of exposure to ESWL. In another trial, Muluk *et al.* [14] reported the findings in 10 patients after one session of ESWL in which they evaluated the patients first before ESWL and then 1 and 15 days after ESWL by TEOAE at different frequencies. They found only a temporary decrease at 3 kHz frequency on 1 day after ESWL application. There was no significant effect at all other frequencies.

Contrary to our results, Iynen *et al.* [15] observed no change in average TEOAEs values even though ESWL treatment was applied during the same day. Virk *et al.* [16] did treat a total of 30 patients with kidney or ureteral stones. Although there was no standardized number of ESWL sessions for each patient, there was no statistically significant difference with respect to TEOAE performed before ESWL and after 2 h of ESWL.

Tuncer *et al.* [17] studied TEOAE test results first before application of ESWL as well as short-term and long-term values after ESWL but they did not find any statistically significant difference.

Videonystagmography test results

In the present study the following abnormalities were detected.

Table 4 Mean and SD of transient evoked otoacoustic emissions overall response in dBSPL in the right and left ears at pre-extracorporeal shock wave lithotripsy and post-extracorporeal shock wave lithotripsy sessions

TEOAEs	Right				*P*	Left				*P*
	Pre-ESWL		Post-ESWL			Pre-ESWL		Post-ESWL		
	Mean	SD	Mean	SD		Mean	SD	Mean	SD	
1000 Hz	11.01	4.49	9.54	4.10	0.177	10.34	4.83	8.35	3.81	0.082
1500 Hz	13.05	5.03	10.94	3.93	0.075	10.51	5.45	8.40	3.89	0.068
2000 Hz	13.00	6.19	8.93	3.95	0.003**	9.88	3.72	7.57	3.48	0.018*
3000 Hz	11.78	5.59	7.55	3.74	0.000**	8.84	4.70	6.43	3.16	0.014*
4000 Hz	7.95	4.67	5.69	3.11	0.031*	6.89	3.33	5.01	2.63	0.016*

ESWL, extracorporeal shock wave lithotripsy; TEOAE, transient evoked otoacoustic emission. *Statistically significant correlation (P<0.05). **Statistically significant correlation (P<0.01).

Table 5 Mean and SD of transient evoked otoacoustic emissions overall response in dBSPL in the right and left ears at pre-extracorporeal shock wave lithotripsy sessions and 2 months follow-up

TEOAEs	Right				*P*	Left				*P*
	Pre-ESWL		Follow up			Pre-ESWL		Follow up		
	Mean	SD	Mean	SD		Mean	SD	Mean	SD	
1000 Hz	11.01	4.49	11.20	4.36	0.868	10.34	4.83	10.53	4.68	0.874
1500 Hz	13.05	5.03	13.15	4.96	0.941	10.51	5.45	10.80	5.10	0.830
2000 Hz	13.00	6.19	13.19	6.06	0.903	9.88	3.72	10.02	3.55	0.886
3000 Hz	11.78	5.59	11.95	5.50	0.907	8.84	4.70	9.03	4.51	0.875
4000 Hz	7.95	4.67	8.06	4.65	0.927	6.89	3.33	7.07	3.15	0.833

ESWL, extracorporeal shock wave lithotripsy; TEOAE, transient evoked otoacoustic emission.

Table 6 Mean and SD of transient evoked otoacoustic emissions overall response in dBSPL in the right and left ears at post-extracorporeal shock wave lithotripsy sessions and 2 months follow-up

TEOAEs	Right				*P*	Left				*P*
	Post-ESWL		Follow up			Post-ESWL		Follow up		
	Mean	SD	Mean	SD		Mean	SD	Mean	SD	
1000 Hz	9.54	4.10	11.20	4.36	0.135	8.35	3.81	10.53	4.68	0.063
1500 Hz	10.94	3.93	13.15	4.96	0.061	8.40	3.89	10.80	5.10	0.057
2000 Hz	8.93	3.95	13.19	6.06	0.002**	7.57	3.48	10.02	3.55	0.009**
3000 Hz	7.55	3.74	11.95	5.50	0.001**	6.43	3.16	9.03	4.51	0.012*
4000 Hz	5.69	3.11	8.06	4.65	0.024*	5.01	2.63	7.07	3.15	0.008**

ESWL, extracorporeal shock wave lithotripsy; TEOAE, transient evoked otoacoustic emission. *Statistically significant correlation (P<0.05). **Statistically significant correlation (P<0.01).

According to posthead shaking test, there were two (6.7%) patients who developed right beating nystagmus and two (6.7%) patients who developed left beating nystagmus in post-ESWL sessions (Table 7).

In positioning test, there were five (16.7%) patients who developed right beating nystagmus and one (3.3%) patient developed left beating nystagmus in post-ESWL sessions (Table 7). In positional test, there were four (13.3%) patients who developed right beating nystagmus in post-ESWL sessions (Tables 7 and 8). In the caloric test, there were two (6.7%) patients who developed unilateral weakness in post-ESWL sessions (Tables 9–14).

Table 7 Results of posthead shaking, positioning, and positional tests in pre-extracorporeal shock wave lithotripsy and post-extracorporeal shock wave lithotripsy sessions

	Pre-ESWL [*n* (%)]	Post-ESWL [*n* (%)]	*P*
Posthead shaking test			
Normal	30 (100.0)	26 (86.7)	0.117
Abnormal	0 (0.0)	4 (13.3)	
Positioning test			
Normal	30 (100.0)	24 (80.0)	0.036*
Abnormal	0 (0.0)	6 (20)	
Positional test			
Normal	30 (100.0)	26 (86.7)	0.038*
Abnormal	0 (0.0)	4 (13.3)	

ESWL, extracorporeal shock wave lithotripsy. *Statistically significant correlation ($P<0.05$).

Table 8 Results of posthead shaking, positioning, and positional tests in post-extracorporeal shock wave lithotripsy and 2 months follow-up

	Post-ESWL [*n* (%)]	Follow up [*n* (%)]	*P*
Posthead shaking			
Normal	26 (86.7)	30 (100.0)	0.117
Abnormal	4 (13.3)	0 (0.0)	
Positioning			
Normal	24 (80.0)	30 (100.0)	0.036*
Abnormal	6 (20)	0 (0.0)	
Positional			
Normal	26 (86.7)	30 (100.0)	0.038*
Abnormal	4 (13.3)	0 (0.0)	

ESWL, extracorporeal shock wave lithotripsy. *Statistically significant difference ($P<0.05$).

Table 9 Caloric test findings in the study group in pre-extracorporeal shock wave lithotripsy and post-extracorporeal shock wave lithotripsy sessions

	Pre-ESWL [*n* (%)]	Post-ESWL [*n* (%)]	*P*
Caloric test			
Normal	30 (100.0)	28 (93.3)	0.150
Unilateral weakness	0 (0.0)	2 (6.7)	
Bilateral weakness	0 (0.0)	0 (0.0)	

ESWL, extracorporeal shock wave lithotripsy.

To explain the hypothesis behind the development of the vestibular disorder in NIHL patients, Shupak *et al.* [3] hypothesized that the anatomical proximity of the vestibular labyrinth and the cochlea, the common arterial blood supply of the cochlea and the vestibular end organ, the similarity of the cochlea and the vestibular hair cell ultrastructure and the ability of the semicircular canals cristae to respond to high intensity noise (Tullio phenomenon); all point to the possibility of vestibular damage associated with NIHL.

Although some patients of the present study had some abnormalities in VNG, but none of patients complained of vertigo. This was explained by Shupak *et al.* [18] the relative low incidence of vertigo in NIHL patients due to the ability of central nervous system to compensate for peripheral vestibular malfunction, because visual and somatosensory input make up for the vestibular deficit. Igarashi [19] reported that vestibular compensation could be maintained when there are adequate sensory stimuli reaching central nervous system.

Conclusion

The results of this study showed that ESWL had a potentially hazardous effect on hearing. The effect of ESWL on hearing was in the form of temporary hearing loss. The effect of ESWL on the vestibular function was less evident. This effect was probably related to the frequency of exposure to ESWL.

Recommendations

(1) Ear protection should be used, such as protective ear-cushions, and not exposing the patient to much noise after the ESWL session if possible.
(2) Lithotripter operators should undergo regular audiometric assessment to monitor the effects of current treatment schedules, and if significant threshold shifts are found these should be investigated fully as they are regularly exposed.
(3) In the future, more detailed studies should be to standardize safer durations between ESWL applications.
(4) More comprehensive vestibular test battery should be applied to detect the vestibular system affection using vestibular-evoked myogenic potential, and vestibular head impulse test (high-frequency vestibular test) to evaluate different anatomical sites and more broad spectrum of frequencies of vestibular system.

Table 10 Relation between number of extracorporeal shock wave lithotripsy sessions and PTA in pre-extracorporeal shock wave lithotripsy, post-extracorporeal shock wave lithotripsy, and after 2 months follow up in the right ears

PTA	One session			*P*1	*P*2	Two sessions			*P*1	*P*2
	Pre	Post	Follow up			Pre	Post	Follow up		
250 Hz	14.6±5.5	16.5±5.5	15.1±5.6	0.104	0.680	15.4±5	16.5±5.8	15.9±5.8	0.423	0.865
500 Hz	14.1±5.7	15.5±4.7	14.6±5.6	0.208	0.697	15.7±4.7	16.7±5	16.1±4.9	0.542	0.848
1000 Hz	14±4.5	15.1±4.9	14.3±4.4	0.262	0.736	12.5±4.7	13.7±4.4	13.2±4.1	0.327	0.524
2000 Hz	15±3.9	16±4.1	15.5±4	0.121	0.518	14.3±3.9	18.6±5.3	14.3±3.9	0.014*	1.000
4000 Hz	15.2±4.6	16.7±3.2	15.9±4.4	0.213	0.448	15.7±3.3	18.2±4.3	15.7±3.3	0.013*	1.000
8000 Hz	17.3±5.2	19.2±4.3	18.2±4.8	0.052	0.386	20±4.4	15.5±5.5	20.4±4.6	0.001**	0.846

ESWL, extracorporeal shock wave lithotripsy. *P*1, relation between number of ESWL sessions and PTA in pre-ESWL and post-ESWL exposure in the right ears.*P*2, relation between number of ESWL sessions and PTA in pre-ESWL and after 2 months follow up in the right ears. *Statistically significant correlation ($P<0.05$). **Statistically significant correlation ($P<0.01$).

Table 11 Relation between number of extracorporeal shock wave lithotripsy sessions and PTA in pre-extracorporeal shock wave lithotripsy, post-extracorporeal shock wave lithotripsy, and after 2 months follow up in the left ears

PTA	One session			*P*1	*P*2	Two sessions			*P*1	*P*2
	Pre	Post	Follow up			Pre	Post	Follow up		
250 Hz	14±5.5	15.9±5.5	14.5±5.6	0.121	0.652	14.8±5	15.9±5.8	15.3±5.8	0.399	0.815
500 Hz	13.6±5.7	14.9±4.7	14±5.6	0.231	0.711	15.1±4.7	16.1±5	15.5±4.9	0.519	0.776
1000 Hz	13.5±4.5	14.5±4.9	13.8±4.4	0.118	0.321	12±4.7	13.2±4.4	12.7±4.1	0.374	0.536
2000 Hz	14.4±3.9	15.4±4.1	14.9±4	0.244	0.324	13.8±3.9	17.9±5.3	13.6±3.7	0.017*	0.929
4000 Hz	14.6±4.6	16.1±3.2	15.3±4.4	0.213	0.419	15.1±3.3	17.5±4.3	15.0±3.2	0.012*	0.988
8000 Hz	16.6±5.2	18.5±4.3	17.5±4.8	0.076	0.411	19.2±4.4	14.9±5.5	19.6±4.6	0.001**	0.882

ESWL, extracorporeal shock wave lithotripsy. *P*1, relation between number of ESWL sessions and PTA in pre-ESWL and post-ESWL exposure in the left ears. *P*2, relation between number of ESWL sessions and PTA in pre-ESWL and after 2 months follow up in the left ears. *Statistically significant correlation ($P<0.05$). **Statistically significant correlation ($P<0.01$).

Table 12 Relation between number of extracorporeal shock wave lithotripsy sessions and transient evoked otoacoustic emissions in pre-extracorporeal shock wave lithotripsy, post-extracorporeal shock wave lithotripsy, and after 2 months follow up in the right ears

TEOAEs	One session			*P*1	*P*2	Two sessions			*P*1	*P*2
	Pre	Post	Follow up			Pre	Post	Follow up		
1000 Hz	10.4±4.8	8.8±4.2	10.6±4.7	0.089	0.878	11.5±4	10.5±3.1	11.8±3.7	0.284	0.80
1500 Hz	11.7±5.5	10±4.4	11.8±5.4	0.106	0.909	12±5.1	10.6±2.8	12.4±4.4	0.193	0.78
2000 Hz	12±5.3	11.4±3.8	12.1±5.2	0.431	0.952	9.6±5.1	6.7±3.8	10.1±4.8	0.015*	0.77
3000 Hz	10.8±5.2	9.4±3.5	10.9±5	0.362	0.871	8.9±5.7	5.7±3	9.1±5.7	0.032*	0.89
4000 Hz	7.2±3.8	6.2±2.7	7.4±3.7	0.112	0.829	8±4.8	5.9±3.4	8.1±4.8	0.044*	0.95

TEOAE, transient evoked otoacoustic emission. *Statistically significant correlation ($P<0.05$).

Table 13 Relation between number of extracorporeal shock wave lithotripsy sessions and transient evoked otoacoustic emissions in pre-extracorporeal shock wave lithotripsy, post-extracorporeal shock wave lithotripsy, and after 2 months follow up in the left ears

TEOAEs	One session			*P*1	*P*2	Two sessions			*P*1	*P*2
	Pre	Post	Follow up			Pre	Post	Follow up		
1000 Hz	10.2±4.8	8.6±4.2	10.4±4.7	0.109	0.812	11.3±4	10.3±3.1	11.6±3.7	0.310	0.821
1500 Hz	11.5±5.5	9.8±4.4	11.6±5.4	0.121	0.912	11.7±5.1	10.4±2.8	12.1±4.4	0.181	0.715
2000 Hz	11.7±5.3	11.2±3.8	11.8±5.2	0.428	0.821	9.4±5.1	6.6±3.8	9.9±4.8	0.016*	0.731
3000 Hz	10.6±5.2	9.2±3.5	10.7±5	0.332	0.809	8.7±5.7	5.6±3	8.9±5.7	0.031*	0.819
4000 Hz	7±3.8	6.1±2.7	7.2±3.7	0.122	0.819	7.8±4.8	5.8±3.4	7.9±4.8	0.046*	0.942

TEOAE, transient evoked otoacoustic emission. *Statistically significant correlation ($P<0.05$).

Table 14 Correlation between age and PTA

	Age					
	Pre-ESWL		Post-ESWL		Follow up	
	R	*P*	*R*	*P*	*R*	*P*
PTA 250 Hz	0.42	0.001**	0.52	0.001**	0.44	0.001**
PTA 500 Hz	0.41	0.001**	0.14	0.297	0.44	0.001**
PTA 1000 Hz	0.28	0.031*	0.30	0.022*	0.30	0.018*
PTA 2000 Hz	0.18	0.166	–0.08	0.553	0.20	0.117
PTA 4000 Hz	0.01	0.930	0.37	0.004**	0.05	0.720
PTA 8000 Hz	0.08	0.520	0.30	0.018*	0.17	0.207

ESWL, extracorporeal shock wave lithotripsy. *Statistically significant correlation ($P<0.05$). **Statistically significant correlation ($P<0.01$).

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Conflicts of interest

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