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DPOAE measurements in comparison to audiometric measurements in hemodialyzed patients

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ABSTRACT

Objective: To investigate the early detection of the damage of cochlear activity by using distortion product otoacoustic emissions (DPOAE) (DP-gram) comparing to the results of the impedance audiometry.

Methods: We examined 53 patients including 43 hemodialyzed patients, and 10 controls. First it was applied a tympanometry, and then in normal results we applied impedance audiometry and DPOAE (DP-gram).

Results: We found sensorineural hearing loss in 67% of audiometric results of the hemodialyzed patients and there was a decrease of the DPOAE amplitude in 77% of hemodialyzed patients. In the control group there was one patient (10%) with neurosensorial in high frequencies hearing loss in both measurements with audiometry and DPOAE.

Conclusions: There is a sensorineural hearing loss observed in most of the patients with chronic renal failure. DPOAE audiogram shows lower amplitudes than impedance audiometry and it can be used for the early detection of cochlear damage.

1. Introduction

Otoacoustic emissions are tests used to determine the hair cell function of the cochlea. So otoacoustic emission testing can be used as a tool to determine the presence or absence of cochlear function and analysis can be performed for individual cochlear frequency regions[1,2]. Another potential use of distortion product otoacoustic emissions (DPOAE) measurements might be to predict auditory response growth, such as growth of loudness. This application would be of interest clinically because one consequence of cochlear hearing loss may be an abnormal growth of loudness, sometimes referred to as loudness recruitment[3].

DPOAEs are sounds emitted in response to 2 simultaneous tones of different frequencies. Stimuli consist of 2 pure tones at 2 frequencies (f2 > f1) and two intensity levels (L1, L2)[4,5]. The relationship between L1–L2 and f1/f2 dictates the frequency response. DPOAEs allow great frequency specificity with a great reliability above 1 000 Hz[6].

Hearing losses above 50 dB HL are not quantifiable using DPOAEs and their performance at frequencies below 1 kHz is limited, but their recording time is short[7].

Presence of hearing loss and estimation of type and degree is one of the most common methods used to investigate the effects of renal disease on the auditory system[8]. Degree of hearing loss may give an indication of the extent of damage to auditory function, whereas the type of hearing loss may distinguish between lesions in the outer and middle ear (conductive hearing loss) or the cochlea and the neural pathways (sensorineural hearing loss)[9]. According to these indicators, the reports to be reviewed in the following sections have also described auditory function in CRF with methods such as tympanometry, audiometry and otoacoustic emissions (distortion product OAEs, DPOAEs).

2. Materials and methods

We analyzed 53 patients (106 ears) including 43 subjects of different stages of renal failure disease undergoing hemodialysis treatment and 10 controls.

The criteria for case selection were: age 15–50 years[10], hearing impairment after the occurrence of renal failure, no history of noise exposure, no history of diabetes, no history of renal transplantation.

The criteria for healthy volunteers were: age 15–50 years, normal renal function tests, no history of noise exposure, no history of diabetes, no history of renal transplantation.

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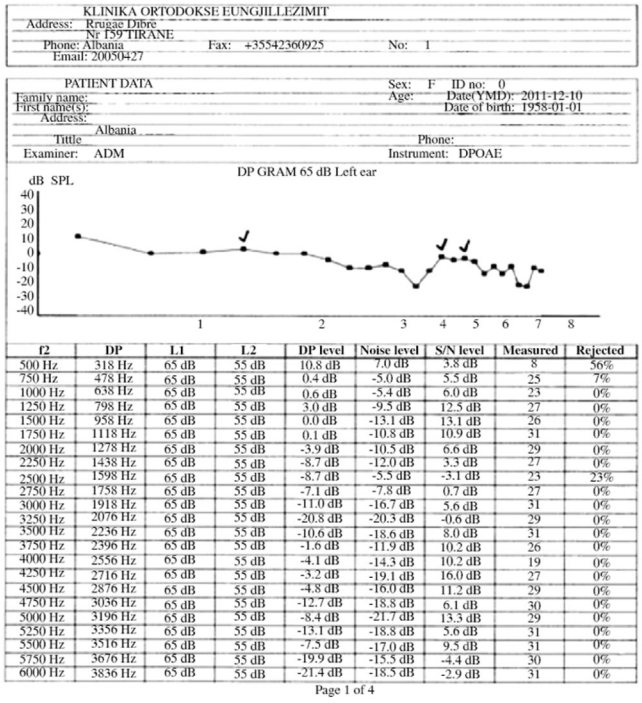
Renal failure was diagnosed by elevated level of blood urea and serum creatinine and associated oliguria. We did hearing evaluation by using tympanometry, impedance audiometry and DPOAE. We used a setting of 65/55 dB SPL L1/L2 in DPOAE examination.

3. Results

According to the results of the examinations done to the patients it showed that 29 patients out of 43 under hemodialysis treatment had sensorineural hearing loss in high frequencies in audiometric measurements and 33 of them had decreased DPOAE amplitudes (Figure 1).

In the control group only one patient had pure tone audiometry (PTA) threshold low in high frequencies and DPOAE gram according to the audiogram but lower values in >4 000 Hz.

It was observed a higher incidence of hearing loss in stages three, four and five of renal failure with lower amplitudes in the DP-gram than PTA thresholds in the same frequencies (Figures 2 and 3).



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Examiner: ADM
Sex: F ID no: 0
Age: Date(YMD): 2011-12-10
Date of birth: 1958-01-01
Phone:
Instrument: DPOAE

DP GRAM 65 dB Left ear

f2	DP	L1	L2	DP level	Noise level	S/N level	Measured	Rejected
500 Hz	318 Hz	65 dB	55 dB	10.8 dB	7.0 dB	3.8 dB	8	56%
750 Hz	478 Hz	65 dB	55 dB	0.4 dB	-5.0 dB	5.5 dB	25	7%
1000 Hz	638 Hz	65 dB	55 dB	0.6 dB	-5.4 dB	6.0 dB	23	0%
1250 Hz	798 Hz	65 dB	55 dB	3.0 dB	-9.5 dB	12.5 dB	27	0%
1500 Hz	958 Hz	65 dB	55 dB	0.0 dB	-13.1 dB	13.1 dB	26	0%
1750 Hz	1118 Hz	65 dB	55 dB	0.1 dB	-10.8 dB	10.9 dB	31	0%
2000 Hz	1278 Hz	65 dB	55 dB	-3.9 dB	-10.5 dB	6.6 dB	29	0%
2250 Hz	1438 Hz	65 dB	55 dB	-8.7 dB	-12.0 dB	3.3 dB	27	0%
2500 Hz	1598 Hz	65 dB	55 dB	-8.7 dB	-5.5 dB	-3.1 dB	23	23%
2750 Hz	1758 Hz	65 dB	55 dB	-7.1 dB	-7.8 dB	0.7 dB	27	0%
3000 Hz	1918 Hz	65 dB	55 dB	-11.0 dB	-16.7 dB	5.6 dB	31	0%
3250 Hz	2076 Hz	65 dB	55 dB	-20.8 dB	-20.3 dB	-0.6 dB	29	0%
3500 Hz	2236 Hz	65 dB	55 dB	-10.6 dB	-18.6 dB	8.0 dB	31	0%
3750 Hz	2396 Hz	65 dB	55 dB	-1.6 dB	-11.9 dB	10.2 dB	26	0%
4000 Hz	2556 Hz	65 dB	55 dB	-4.1 dB	-14.3 dB	10.2 dB	19	0%
4250 Hz	2716 Hz	65 dB	55 dB	-3.2 dB	-19.1 dB	16.0 dB	27	0%
4500 Hz	2876 Hz	65 dB	55 dB	-4.8 dB	-16.0 dB	11.2 dB	29	0%
4750 Hz	3036 Hz	65 dB	55 dB	-12.7 dB	-18.8 dB	6.1 dB	30	0%
5000 Hz	3196 Hz	65 dB	55 dB	-8.4 dB	-21.7 dB	13.3 dB	29	0%
5250 Hz	3356 Hz	65 dB	55 dB	-13.1 dB	-18.8 dB	5.6 dB	31	0%
5500 Hz	3516 Hz	65 dB	55 dB	-7.5 dB	-17.0 dB	9.5 dB	31	0%
5750 Hz	3676 Hz	65 dB	55 dB	-19.9 dB	-15.5 dB	-4.4 dB	30	0%
6000 Hz	3836 Hz	65 dB	55 dB	-21.4 dB	-18.5 dB	-2.9 dB	31	0%

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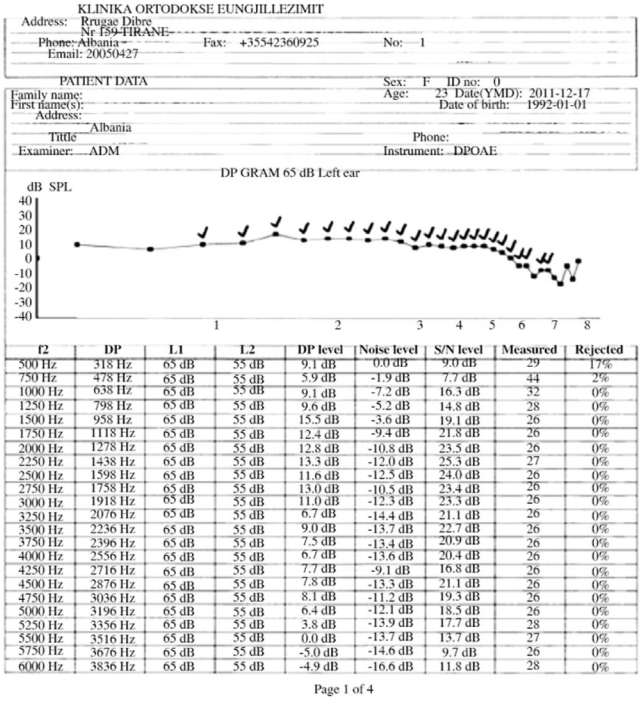

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Sex: F ID no: 0
Age: 23 Date(YMD): 2011-12-17
Date of birth: 1992-01-01
Phone:
Instrument: DPOAE

DP GRAM 65 dB Left ear

f2	DP	L1	L2	DP level	Noise level	S/N level	Measured	Rejected
500 Hz	318 Hz	65 dB	55 dB	9.1 dB	0.0 dB	9.0 dB	29	17%
750 Hz	478 Hz	65 dB	55 dB	5.9 dB	-1.9 dB	7.7 dB	44	2%
1000 Hz	638 Hz	65 dB	55 dB	9.1 dB	-7.2 dB	16.3 dB	32	0%
1250 Hz	798 Hz	65 dB	55 dB	9.6 dB	-5.2 dB	14.8 dB	28	0%
1500 Hz	958 Hz	65 dB	55 dB	15.5 dB	-3.6 dB	19.1 dB	26	0%
1750 Hz	1118 Hz	65 dB	55 dB	12.4 dB	-9.4 dB	21.8 dB	26	0%
2000 Hz	1278 Hz	65 dB	55 dB	12.8 dB	-10.8 dB	23.5 dB	26	0%
2250 Hz	1438 Hz	65 dB	55 dB	13.3 dB	-12.0 dB	25.3 dB	27	0%
2500 Hz	1598 Hz	65 dB	55 dB	11.6 dB	-12.5 dB	24.0 dB	26	0%
2750 Hz	1758 Hz	65 dB	55 dB	13.0 dB	-10.5 dB	23.4 dB	26	0%
3000 Hz	1918 Hz	65 dB	55 dB	11.0 dB	-12.3 dB	23.3 dB	26	0%
3250 Hz	2076 Hz	65 dB	55 dB	6.7 dB	-14.4 dB	21.1 dB	26	0%
3500 Hz	2236 Hz	65 dB	55 dB	9.0 dB	-13.7 dB	22.7 dB	26	0%
3750 Hz	2396 Hz	65 dB	55 dB	7.5 dB	-13.4 dB	20.9 dB	26	0%
4000 Hz	2556 Hz	65 dB	55 dB	6.7 dB	-13.6 dB	20.4 dB	26	0%
4250 Hz	2716 Hz	65 dB	55 dB	7.7 dB	-9.1 dB	16.8 dB	26	0%
4500 Hz	2876 Hz	65 dB	55 dB	7.8 dB	-13.3 dB	21.1 dB	26	0%
4750 Hz	3036 Hz	65 dB	55 dB	8.1 dB	-11.2 dB	19.3 dB	26	0%
5000 Hz	3196 Hz	65 dB	55 dB	6.4 dB	-12.1 dB	18.5 dB	26	0%
5250 Hz	3356 Hz	65 dB	55 dB	3.8 dB	-13.9 dB	17.7 dB	28	0%
5500 Hz	3516 Hz	65 dB	55 dB	0.0 dB	-13.7 dB	13.7 dB	27	0%
5750 Hz	3676 Hz	65 dB	55 dB	-5.0 dB	-14.6 dB	9.7 dB	26	0%
6000 Hz	3836 Hz	65 dB	55 dB	-4.9 dB	-16.6 dB	11.8 dB	28	0%

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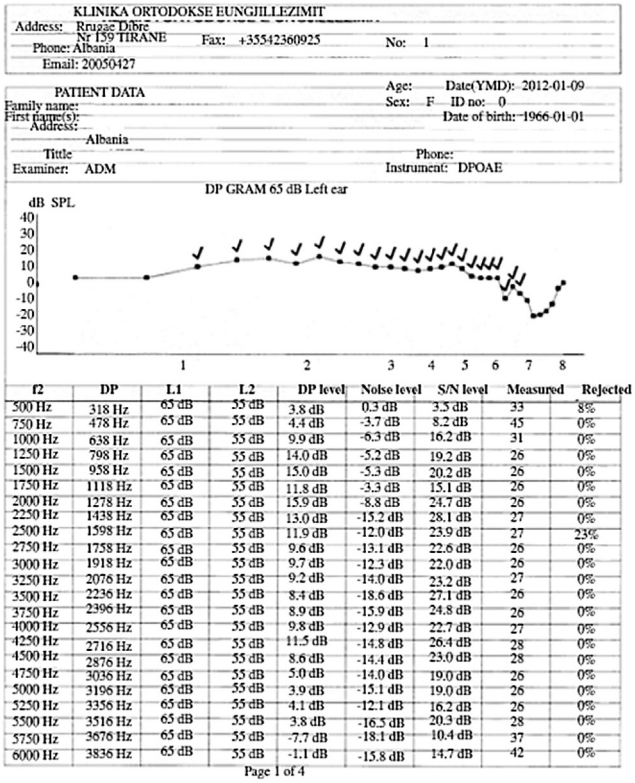
Figure 1. DPOAE findings in CRF patients.



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Examiner: ADM
Age: Date(YMD): 2012-01-09
Sex: F ID no: 0
Date of birth: 1966-01-01
Phone:
Instrument: DPOAE

DP GRAM 65 dB Left ear

f2	DP	L1	L2	DP level	Noise level	S/N level	Measured	Rejected
500 Hz	318 Hz	65 dB	55 dB	3.8 dB	0.3 dB	3.5 dB	33	8%
750 Hz	478 Hz	65 dB	55 dB	4.4 dB	-3.7 dB	8.2 dB	45	0%
1000 Hz	638 Hz	65 dB	55 dB	9.9 dB	-6.3 dB	16.2 dB	31	0%
1250 Hz	798 Hz	65 dB	55 dB	14.0 dB	-5.2 dB	19.2 dB	26	0%
1500 Hz	958 Hz	65 dB	55 dB	15.0 dB	-5.3 dB	20.2 dB	26	0%
1750 Hz	1118 Hz	65 dB	55 dB	11.8 dB	-3.3 dB	15.1 dB	26	0%
2000 Hz	1278 Hz	65 dB	55 dB	15.9 dB	-8.8 dB	24.7 dB	26	0%
2250 Hz	1438 Hz	65 dB	55 dB	13.0 dB	-15.2 dB	28.1 dB	27	0%
2500 Hz	1598 Hz	65 dB	55 dB	11.9 dB	-12.0 dB	23.9 dB	27	23%
2750 Hz	1758 Hz	65 dB	55 dB	9.6 dB	-13.1 dB	22.6 dB	26	0%
3000 Hz	1918 Hz	65 dB	55 dB	9.7 dB	-12.3 dB	22.0 dB	26	0%
3250 Hz	2076 Hz	65 dB	55 dB	9.2 dB	-14.0 dB	23.2 dB	27	0%
3500 Hz	2236 Hz	65 dB	55 dB	8.4 dB	-18.6 dB	27.1 dB	26	0%
3750 Hz	2396 Hz	65 dB	55 dB	8.9 dB	-15.9 dB	24.8 dB	26	0%
4000 Hz	2556 Hz	65 dB	55 dB	9.8 dB	-12.9 dB	22.7 dB	27	0%
4250 Hz	2716 Hz	65 dB	55 dB	11.5 dB	-14.8 dB	26.4 dB	28	0%
4500 Hz	2876 Hz	65 dB	55 dB	8.6 dB	-14.4 dB	23.0 dB	28	0%
4750 Hz	3036 Hz	65 dB	55 dB	5.0 dB	-14.0 dB	19.0 dB	26	0%
5000 Hz	3196 Hz	65 dB	55 dB	3.9 dB	-15.1 dB	19.0 dB	26	0%
5250 Hz	3356 Hz	65 dB	55 dB	4.1 dB	-12.1 dB	16.2 dB	26	0%
5500 Hz	3516 Hz	65 dB	55 dB	3.8 dB	-16.5 dB	20.3 dB	28	0%
5750 Hz	3676 Hz	65 dB	55 dB	-7.7 dB	-18.1 dB	10.4 dB	37	0%
6000 Hz	3836 Hz	65 dB	55 dB	-1.1 dB	-15.8 dB	14.7 dB	42	0%

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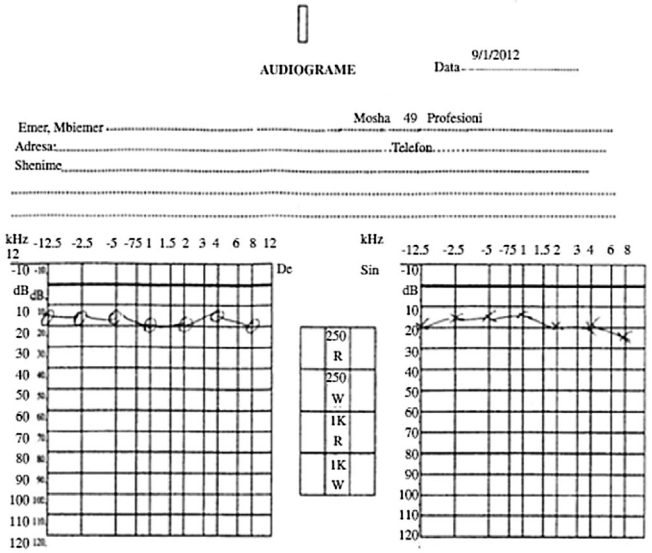
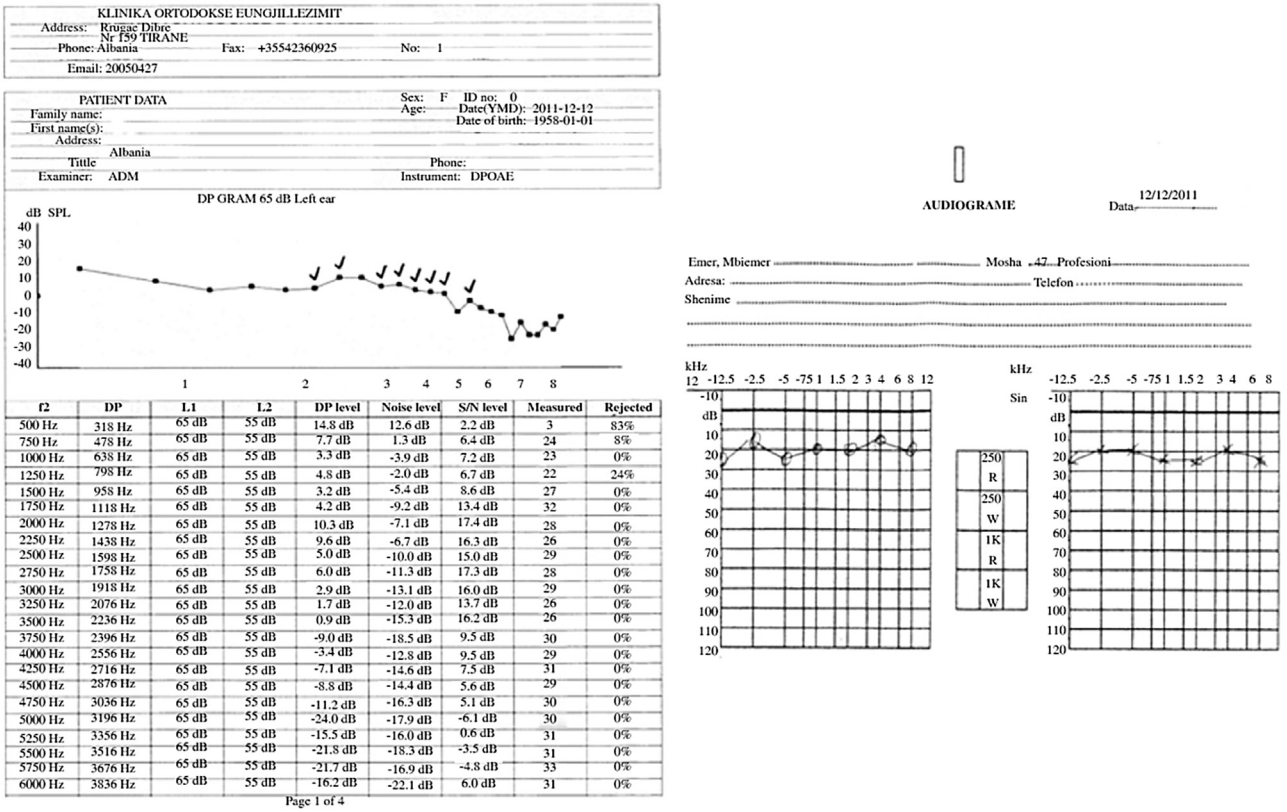


Figure 2. DPOAE and audiometric results of one of our patients.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Examiner: ADM
Sex: F ID no: 0
Age: Date(YMD): 2011-12-12
Date of birth: 1958-01-01
Phone:
Instrument: DPOAE

DP GRAM 65 dB Left ear

f2	DP	L1	L2	DP level	Noise level	S/N level	Measured	Rejected
500 Hz	318 Hz	65 dB	55 dB	14.8 dB	12.6 dB	2.2 dB	3	83%
750 Hz	478 Hz	65 dB	55 dB	7.7 dB	1.3 dB	6.4 dB	24	8%
1000 Hz	638 Hz	65 dB	55 dB	3.3 dB	-3.9 dB	7.2 dB	23	0%
1250 Hz	798 Hz	65 dB	55 dB	4.8 dB	-2.0 dB	6.7 dB	22	24%
1500 Hz	958 Hz	65 dB	55 dB	3.2 dB	-5.4 dB	8.6 dB	27	0%
1750 Hz	1118 Hz	65 dB	55 dB	4.2 dB	-9.2 dB	13.4 dB	32	0%
2000 Hz	1278 Hz	65 dB	55 dB	10.3 dB	-7.1 dB	17.4 dB	28	0%
2250 Hz	1438 Hz	65 dB	55 dB	9.6 dB	-6.7 dB	16.3 dB	26	0%
2500 Hz	1598 Hz	65 dB	55 dB	5.0 dB	-10.0 dB	15.0 dB	29	0%
2750 Hz	1758 Hz	65 dB	55 dB	6.0 dB	-11.3 dB	17.3 dB	28	0%
3000 Hz	1918 Hz	65 dB	55 dB	2.9 dB	-13.1 dB	16.0 dB	29	0%
3250 Hz	2076 Hz	65 dB	55 dB	1.7 dB	-12.0 dB	13.7 dB	26	0%
3500 Hz	2236 Hz	65 dB	55 dB	0.9 dB	-15.3 dB	16.2 dB	26	0%
3750 Hz	2396 Hz	65 dB	55 dB	-9.0 dB	-18.5 dB	9.5 dB	30	0%
4000 Hz	2556 Hz	65 dB	55 dB	-3.4 dB	-12.8 dB	9.5 dB	29	0%
4250 Hz	2716 Hz	65 dB	55 dB	-7.1 dB	-14.6 dB	7.5 dB	31	0%
4500 Hz	2876 Hz	65 dB	55 dB	-8.8 dB	-14.4 dB	5.6 dB	29	0%
4750 Hz	3036 Hz	65 dB	55 dB	-11.2 dB	-16.3 dB	5.1 dB	30	0%
5000 Hz	3196 Hz	65 dB	55 dB	-24.0 dB	-17.9 dB	-6.1 dB	30	0%
5250 Hz	3356 Hz	65 dB	55 dB	-15.5 dB	-16.0 dB	0.6 dB	31	0%
5500 Hz	3516 Hz	65 dB	55 dB	-21.8 dB	-18.3 dB	-3.5 dB	31	0%
5750 Hz	3676 Hz	65 dB	55 dB	-21.7 dB	-16.9 dB	-4.8 dB	33	0%
6000 Hz	3836 Hz	65 dB	55 dB	-16.2 dB	-22.1 dB	6.0 dB	31	0%

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AUDIOGRAME Data 12/12/2011

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Shenime

Figure 3. DPOAE and audiometric results, second patient.

4. Discussion

The survival of chronic renal failure patients is increased with the new hemodialysis treatments[11].

The impact of hearing loss on these patients in the social integration has to be addressed. So both primary prevention and early detection of hearing loss are important for providing management options.

As screening tools, DPOAEs are superior to PTA testing. DPOAE amplitude reduces significantly before behavioral threshold changes are noted at corresponding frequencies in PTA. Decreased emissions in the presence of normal behavioral hearing may indicate an underlying pathologic condition, which if continued might soon result in a significant hearing loss[12]. In this sense, the DP-grams may be predictive, foretelling a substantial threshold shift for a given frequency before a measurable sensitivity loss[13].

Our study demonstrated that DP-grams seem to be a more sensitive test than PTA for determining cochlear dysfunction.

DPOAEs have an extensive dynamic range regarding hearing loss and can be measured over a broader frequency range with more sensitive frequency specific response[14]. With their high sensitivity and excellent reliability, their objectivity makes them ideal for testing patients who cannot cooperate in a traditional examination of behavioral hearing. Their recording is easy for both technician and patient, and can be easily performed at the bedside. DPOAE audiograms provide a tool for a fast automated frequency-specific and quantitative evaluation of a mild or moderate hearing in follow-up diagnosis[15].

Therefore after a complete audiometric valuation it has to be established to monitor these patients periodically using DP-grams alone causing less inconvenience to these patients who are not feeling well.

Conflict of interest statement

The authors report no conflict of interest.

References

[1] Stamper GC, Johnson TA. Auditory function in normal-hearing, noise-exposed human ears. *Ear Hear* 2015; **36**(2): 172-84.

[2] Reavis KM, McMillan G, Austin D, Gallun F, Fausti SA, Gordon JS, et al. Distortion-product otoacoustic emission test performance for ototoxicity monitoring. *Ear Hear* 2011; **32**(1): 61-74.

[3] Thorson MJ, Kopun JG, Neely ST, Tan HY, Gorga MP. Reliability of distortion-product otoacoustic emissions and their relation to loudness. *J Acoust Soc Am* 2012; **131**(2): 1282-95.

[4] Kirby BJ, Kopun JG, Tan H, Neely ST, Gorga MP. Do "optimal" conditions improve distortion product otoacoustic emission test performance? *Ear Hear* 2011; **32**(2): 230-7.

[5] Reuven ML, Neely ST, Kopun JG, Rasetshwane DM, Allen JB, Tan H, et al. Effect of calibration method on distortion-product otoacoustic emission measurements at and around 4 kHz. *Ear Hear* 2013; **34**(6): 779-88.

[6] Shiomi Y, Tsuji J, Naito Y, Fujiki N, Yamamoto N. Characteristics of DPOAE audiogram in tinnitus patients. *Hear Res* 1997; **108**(1–2): 83-8.

[7] Rosner T, Kandzia F, Oswald JA, Janssen T. Hearing threshold estimation using concurrent measurement of distortion product otoacoustic emissions and auditory steady-state responses. *J Acoust Soc Am* 2011; **129**(2): 840-51.

[8] Stavroulaki P, Nikolopoulos TP, Psarommatis I, Apostolopoulos N. Hearing evaluation with distortion-product otoacoustic emissions in young patients undergoing haemodialysis. *Clin Otolaryngol Allied Sci* 2001; **26**(3): 235-42.

[9] Gierek T, Markowski J, Kokot F, Paluch J, Wiecek A, Klimek D. [Electrophysiological examinations (ABR and DPOAE) of hearing organ in hemodialysed patients suffering from chronic renal failure]. *Otolaryngol Pol* 2002; **56**(2): 189-94. Polish.

[10] Lisowska G, Namyslowski G, Orecka B, Misiolek M. Influence of aging on medial olivocochlear system function. *Clin Interv Aging* 2014; **9**: 901-14.

[11] Shi Y, Martin WH. ABR and DPOAE detection of cochlear damage by gentamicin. *J Basic Clin Physiol Pharmacol* 1997; **8**(3): 141-55.

[12] Stavrulaki P, Apostolopulos N, Segas J, Tsakanikos M, Adamopoulos G. Evoked otoacustic emissions-an approach for monitoring cisplatin induced ototoxicity in children. *Int J Pediatr Otorhinolaringol* 2001; **59**(1): 47-57.

[13] Barron SE, Daigneault EA. Effect of cisplatin on hair cell morphology and lateral wall Na, K-ATPase activity. *Hear Res* 1987; **26**(2): 131-7.

[14] Franklin DJ, McCoy MJ, Martin GK, Lonsbury-Martin BL. Test/retest reliability of distortion-product and transiently evoked otoacoustic emissions. *Ear Hear* 1992; **13**(6): 417-29.

[15] Janssen T. A review of the effectiveness of otoacoustic emissions for evaluating hearing status after newborn screening. *Otol Neurotol* 2013; **34**(6): 1058-63.