International Journal of Research and Review
www.gkpublication.in E-ISSN: 2349-9788; P-ISSN: 2454-2237

*Original Research Article*

# A Study to Predict Hearing Loss in Patients Undergoing Hemodialysis by Using DPOAE

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*Received: 28/01/2016* *Revised: 19/02/2016* *Accepted: 25/02/2016*

## ABSTRACT

**Background:** Chronic renal failure (CRF) is characterized by gradually progressive loss of renal function. Incidence of sensorineural hearing (SNHL) loss in patients with chronic renal failure and on regular haemodialysis ranges from 20 to 75%. This study was done to compare the effectiveness of distortion product otoacoustic emissions (DPOAE) in early detection of Haemodialysis associated hearing loss as compared to pure tone audiometry (PTA).
**Methods:** Single Center, prospective study over a 2 year period.50 subjects were evaluated for hearing before undergoing haemodialysis and after 3rd and 5th session of haemodialysis. The patients were evaluated for hearing by PTA and DPOAE.
**Results:** There was a significant difference in mean PTA thresholds and DPOAE amplitudes before and after 3 and 5 sessions of haemodialysis. Furthermore, patients' ears with normal PTA thresholds also had decreased DPOAE amplitudes.
**Conclusion:** DPOAEs seem to be more sensitive to incipient cochlear damage than behaviour thresholds in monitoring renal patients. Sensorineural hearing loss especially in high frequencies is frequent in patients under Haemodialysis.

***Keywords:*** haemodialysis, otoacoustic emissions, pure tone audiometry.

## INTRODUCTION

Incidence of sensorineural hearing (SNHL) loss among patients with chronic renal failure is considerably higher than in the general population. Its incidence in patients with chronic renal failure and on regular hemodialysis ranges from 20 to 75%. *Bazzi et al*. [1] found an incidence of 77% including patients with mild and very mild hearing loss. *Ozturan and Lam* [2] reported a moderate to severe hearing loss in 46% of the patients. *Bergstrom et al*. [3] reported hearing loss in 40% of the CRF patients on haemodialysis. The general consensus in audiometric findings among patients with CRF claims a high frequency hearing loss [4] with a notch at 6 kHz. [2] The aetiopathogenetic mechanisms responsible for sensorineural hearing loss included osmotic alteration resulting in loss of hair cells, oedema and atrophy of specialized auditory cells, collapse of the endolymphatic space along with complications of haemodialysis. [5] The cochlea in patients of chronic renal failure undergoing treatment with haemodialysis has been reported to be susceptible to various insults and the patients often exhibit some amount of hearing loss, although the etiological factor(s) responsible are still

controversial. [6] Some authors have reported a depression in hearing threshold after haemodialysis while others are of the opinion that there was no relation between the two. [7] These auditory functions in CRF patients are estimated by methods such as otoacoustic emissions (OAEs) mainly Distortion Product OAEs (*DPOAEs*) and Pure Tone Audiometry (PTA). This study was planned at department of Otorhinolaryngology, in a tertiary care centre to study the effect of haemodialysis on hearing loss and to assess the effectiveness of DPOAE as a diagnostic tool in early detection of haemodialysis induced hearing loss as compared to PTA.

## MATERIALS AND METHODS

**Subjects:** 50 subjects were selected from consenting patients of chronic renal disease who have not undergone previous haemodialysis as part of their treatment. Patients who were previously treated with haemodialysis, those with features of Uraemic encephalopathy or severe illness and history of chronic otitis media were excluded from the study.

**Audiological procedures:** All 50 subjects were evaluated for hearing before undergoing haemodialysis and after 3$^{rd}$ and 5$^{th}$ session of haemodialysis by PTA using AD19 Diagnostic Audiometer and DPOAE by using ICS Chartr Madsen Capella. An otological examination was carried out to exclude middle ear pathology and conductive hearing loss. Frequency specific air conduction (AC) and bone conduction (BC) thresholds from 250 to 8000 Hz. PTA was performed on each patient in soundproof room on a calibrated diagnostic audiometer, thus ensuring test-retest reliability.

Frequency specific amplitudes of DPOAE was measured from DP-Gram for f2/f1 ratio of 1.22 and L1/L2 of 65/55dB for frequencies from 250-8000 Hz. Amplitude was considered a function of f2 frequency at fixed stimuli levels (DP-grams). The DP-gram amplitude across the entire frequency range was determined for each patient which was compared with the normative data.

**Hearing evaluation and Analysis:** Normal hearing was considered for thresholds less than 20 dB from 250-8000 Hz. A change of more than 10 dB in one or more frequencies was chosen to represent a significant fluctuation in hearing. The DP-gram amplitude across the entire frequency range was determined for each patient which was compared with the normative data.

***Statistical analysis:*** *Chi-Square test* was applied for comparison of nominal data. For continuous variable, paired *t test* was applied to compare within group findings *(Pre Vs Post).* p value of <0.05 was considered as statistically significant. The data was analysed using SPSS (Statistical package for social sciences).

## RESULTS

From November 2010 to August 2012 a total of 50 patients of chronic renal failure were assessed. The demographic profile of these patients was as per table 1.

**Table 1: Age distribution of the patients**

| Age (yrs) | N (%) | | Total |
|---|---|---|---|
| | Female | Male | |
| < 40 | 0 | 7 (20.00%) | 7(14.00%) |
| 40-50 | 10 (66.67%) | 13 (37.14%) | 23(46.00%) |
| > 50 | 5 (33.33%) | 15(42.86%) | 20(40.00%) |
| **Grand Total** | **15** | **35** | **50** |

For right ear there was statistically significant change in mean AC thresholds before and after 3 sessions of haemodialysis in frequencies from 250-1kHz, 3kHz, 6kHz and 8 kHz. There was statistically significant change in mean AC thresholds before and after 5 sessions of haemodialysis in all the frequencies from 250-8kHz (table 2).

For left ear there was statistically significant change in mean thresholds before and after 3 sessions of haemodialysis in frequencies at 250Hz, 1kHz, 2kHz, 3kHz, 4kHz and 8kHz. There was statistically significant change in mean thresholds before and after 5 sessions of haemodialysis in all the frequencies from 250-8kHz (table 3).

**Table 2: Change in AC threshold shift from baseline after haemodialysis (Right ear)**

| AC Frequency (Hz) | Before haemodialysis (dB) | | After 03 Sessions (dB) | | After 05 Sessions (dB) | | P value (Before Vs 03 sessions) | P value (Before Vs 05 sessions) |
|---|---|---|---|---|---|---|---|---|
| | Mean | SD | Mean | SD | Mean | SD | | |
| 250 | 8 | 2.47 | 8.5 | 2.31 | 13.5 | 2.31 | 0.024 | 0.001 |
| 500 | 8 | 2.47 | 8.5 | 2.31 | 13.5 | 2.31 | 0.024 | 0.001 |
| 1000 | 12 | 2.47 | 8.5 | 2.31 | 8 | 2.47 | 0.001 | 0.001 |
| 2000 | 8 | 3.03 | 8.3 | 3.86 | 11.3 | 2.82 | 0.08 | 0.001 |
| 3000 | 11 | 4.95 | 13 | 2.47 | 19 | 3.78 | 0.001 | 0.001 |
| 4000 | 14 | 3.78 | 15 | 8.45 | 19.3 | 8.21 | 0.16 | 0.001 |
| 6000 | 13 | 2.47 | 17.7 | 6.64 | 21 | 10.15 | 0.001 | 0.001 |
| 8000 | 18 | 2.47 | 19.7 | 4.33 | 21.6 | 10.22 | 0.001 | 0.001 |

Paired t test is applied. P value is significant if <0.05.

**Table 3: Change in AC threshold shift from baseline after haemodialysis (Left ear).**

| AC Frequency (Hz) | Before haemodialysis (dB) | | After 03 Sessions (dB) | | After 05 Sessions (dB) | | P value (Before Vs 03 sessions) | P value (Before Vs 05 sessions) |
|---|---|---|---|---|---|---|---|---|
| | Mean | SD | Mean | SD | Mean | SD | | |
| 250 | 5.10 | 0.71 | 9.50 | 1.52 | 10.10 | 0.71 | 0.001 | 0.001 |
| 500 | 5.10 | 0.71 | 5.10 | 0.71 | 10.10 | 0.71 | 1.0 | 0.001 |
| 1000 | 10.10 | 0.71 | 5.10 | 0.71 | 5.10 | 0.71 | 0.001 | 0.001 |
| 2000 | 11.00 | 2.02 | 10.20 | 1.41 | 8.10 | 3.33 | 0.03 | 0.001 |
| 3000 | 13.00 | 2.47 | 11.00 | 4.95 | 14.80 | 4.40 | 0.001 | 0.001 |
| 4000 | 11.00 | 4.95 | 16.00 | 4.95 | 16.30 | 9.47 | 0.001 | 0.001 |
| 6000 | 13.00 | 2.47 | 14.50 | 7.97 | 21.60 | 10.22 | 0.06 | 0.001 |
| 8000 | 13.10 | 2.65 | 16.50 | 5.56 | 21.70 | 10.23 | 0.001 | 0.001 |

Paired t test is applied. P value is significant if <0.05

**Table 4: Change in DPOAE amplitude from baseline after haemodialysis (Right ear).**

| DPOAE Frequency (Hz) | Before haemodialysis (dB) | | After 03 Sessions (dB) | | After 05 Sessions (dB) | | P value (Before Vs 03 sessions) | P value (Before Vs 05 sessions) |
|---|---|---|---|---|---|---|---|---|
| | Mean | SD | Mean | SD | Mean | SD | | |
| 250 | 6.36 | 0.32 | 6.52 | 0.39 | 6.44 | 0.37 | 0.001 | 0.001 |
| 500 | 6.43 | 0.20 | 6.39 | 0.17 | 6.29 | 0.14 | 0.001 | 0.001 |
| 1000 | 6.97 | 0.05 | 6.91 | 0.03 | 6.83 | 0.07 | 0.001 | 0.001 |
| 2000 | 7.56 | 1.09 | 7.20 | 1.10 | 7.07 | 1.36 | 0.001 | 0.001 |
| 3000 | 4.15 | 2.77 | 3.83 | 2.92 | 3.48 | 3.07 | 0.001 | 0.001 |
| 4000 | 1.37 | 4.84 | 0.58 | 4.94 | 0.12 | 5.29 | 0.001 | 0.001 |
| 6000 | 0.27 | 4.88 | -0.29 | 5.18 | -0.83 | 5.54 | 0.001 | 0.001 |
| 8000 | -1.78 | 4.50 | -2.20 | 4.66 | -2.60 | 4.91 | 0.001 | 0.001 |

Paired t test is applied. P value is significant if <0.05.

**Table 5: Change in DPOAE amplitude from baseline after haemodialysis (Left ear)**

| Frequency (Hz) | Before haemodialysis (dB) | | After 03 Sessions (dB) | | After 05 Sessions (dB) | | P value (Before Vs 03 sessions) | P value (Before Vs 05 sessions) |
|---|---|---|---|---|---|---|---|---|
| | Mean | SD | Mean | SD | Mean | SD | | |
| 250 | 6.30 | 0.14 | 6.22 | 0.06 | 6.10 | 0.04 | 0.001 | 0.001 |
| 500 | 6.22 | 0.06 | 6.29 | 0.03 | 6.30 | 0.02 | 0.001 | 0.001 |
| 1000 | 6.97 | 0.05 | 6.78 | 0.04 | 6.70 | 0.01 | 0.001 | 0.001 |
| 2000 | 7.63 | 1.20 | 7.11 | 1.18 | 7.36 | 1.32 | 0.001 | 0.001 |
| 3000 | 4.35 | 2.64 | 3.92 | 2.82 | 3.06 | 3.61 | 0.001 | 0.001 |
| 4000 | 1.24 | 4.81 | 0.47 | 5.07 | 0.07 | 5.37 | 0.001 | 0.001 |
| 6000 | 0.19 | 5.15 | 0.01 | 5.41 | -0.67 | 5.90 | 0.001 | 0.001 |
| 8000 | -1.83 | 4.45 | -1.98 | 4.49 | -2.56 | 5.12 | 0.001 | 0.001 |

Paired t test is applied. P value is significant if <0.05.

Bone conduction figures were consistent with air conduction thresholds but were omitted from figures for the sake of clarity. There was statistically significant change in mean DPOAE amplitudes before and after 3 and 5 sessions of haemodialysis in all the frequencies from 250-8 kHz for both the ears (table 4, 5).

## DISCUSSION

The cochlea and kidney have similar physiological mechanisms, which include the active transport of electrolytes and fluid by the stria vascularis and the glomerulus, respectively. [8] They may also have common antigenicity. [9] These may account for similar effects of medications (i.e. nephrotoxic and ototoxic effects of aminoglycosides) and immunological factors on the two organs. Various studies

have shown loss of outer hair cells, deposition of blue staining concretions in the layers of stria vascularis with and without strial degeneration, shrinkage of tectorial membrane, degeneration of organ of corti & stria vascularis, thickening of Reissner's membrane and rupture of endolymphatic sac. [10]

Pure tone audiometry (PTA) is the basic hearing test used to identify hearing threshold levels of an individual. However, PTA is a subjective, behavioral measurement of hearing threshold, as the results are dependent on patient's response to pure tone stimuli.

DPOAEs are an objective indicator of normally functioning cochlear outer hair cells. The response is actual intermodulation distortion product produced by the ear when stimulated by two closely spaced tones. Most robust DPOAE response is obtained when the ratio of two frequencies is 1.22:1.

On one hand there is PTA, which is the conventional standard for assessment of a hearing loss but being a subjective test its accuracy is still not established and on the other hand there is DPOAE which is noninvasive, objective, rapid, easy to use and sensitive.

In our study there were a total of 50 patients, out of these 50 patients, 35 were male and 15 were female. The age distribution of our patients was, 7 patients were below the age of 40 yrs, 23 were between the age of 40-50 yrs, 20 patients were above the age of 50 yrs ( table 1).

*Gatland et al*. [6] recorded pure tone thresholds on 31 patients before and after a session of haemodialysis. They included 125Hz frequency in the study and documented a low frequency hearing loss, which improved significantly in 33 % of the patients after 3 sessions of dialysis. As low-frequency sensorineural hearing loss is related to endolymphatic hydrops, they reported that changes in fluid balance during haemodialysis may be accountable for the hearing improvement in low frequency. *Lasisi O* et al *in* 33 CRF patients treated with haemodialysis; there was significant difference between the mean pre- and post-hemodialysis pure tone audiometry (PTA) values. DPOAE was not done due to lack of availability of instrument. [11] In our study there was a significant ($p<0.05$) difference between the mean AC hearing thresholds for both the ears before haemodialysis and after 3 and 5 sessions of haemodialysis in the frequencies from 250 to 8000 Hz except in few frequencies after 3 sessions of haemodialysis as measured by pure tone audiometry (table 2 and 3). Thus, our study has shown significant depression in hearing thresholds after 3 and 5 sessions of haemodialysis. *Bergstrom* et al. [3] reported hearing loss in 40% of the CRF patients on haemodialysis. *Johnson and Mathog* [5] noted high frequency hearing loss in 61 adults early in the course of haemodialysis. *Bergstrom and Thompson* [12] reported that 47% of 151 paediatric end-stage renal patients had hearing loss. Hearing loss is a more common finding than vestibular dysfunction. *Kusakari et al.* [13] reported on inner ear function of 229 patients on chronic haemodialysis. They found that 60% had hearing loss, 36% had vestibular dysfunction and 26% had a combination of both

*Stavroulaki P* et al [14] assessed the effect of a single session of haemodialysis on hearing acuity in nine children with end-stage renal disease using pure-tone audiometry (PTA) and DPOAEs. No significant changes in PTA thresholds or DPOAE amplitudes were encountered in renal patients before and after a HD session ($P > 0.05$). *Chu PL* et al [15] assessed 40 patients in maintenance HD as well as 40 age-matched healthy subjects without hearing complaints. High-frequency hearing impairment was the predominant auditory dysfunction in HD patients who showed worse high-tone hearing level on PTA and diminished amplitudes of DPOAEs at 3000Hz and 4000Hz as compared with the controls.

In our study the difference in mean DPOAE amplitudes for both ears before haemodialysis and after 3 and 5 sessions of

haemodialysis were statistically significant ($p<.05$) for all frequencies from 250 Hz to 8000 Hz ( table 4 and 5). Thus, our results indicate that in patients with chronic renal failure on haemodialysis the ability of the cochlea to generate DPOAE appears to be significantly decreased. *Samir* et al. [16] also reported similar findings; corroborating the hypothesis that children with CRF (on haemodialysis) may have signs of adverse effects on function of cochlea, which might be foretelling and predictive of upcoming hearing loss.

Our study also showed that number of patients who had significant change in the hearing thresholds (≥10 dB) as measured by pure tone audiometry were more after 5 sessions of haemodialysis than 3 sessions of haemodialysis mainly in frequencies from 3000 to 8000 Hz (fig 1 and 2).

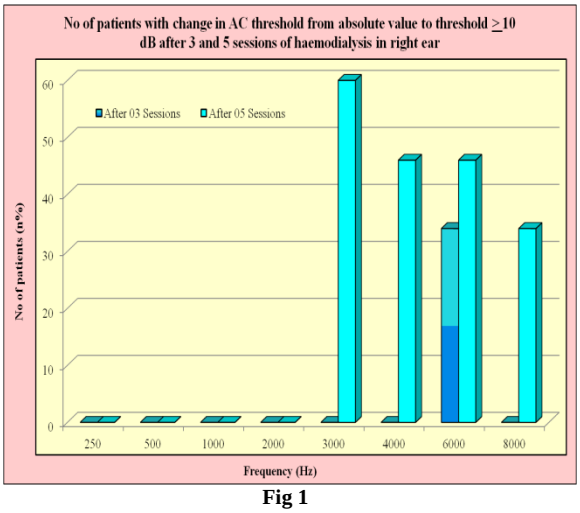


**Fig 1**

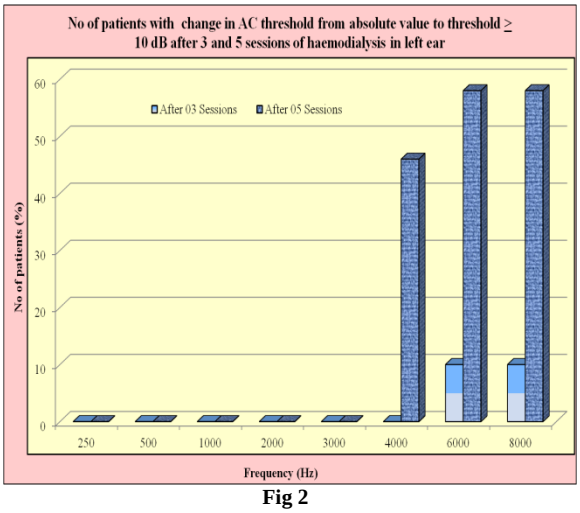


**Fig 2**

There were 30(60%) patients who had hearing loss after 3 and 5 sessions of haemodialysis mainly in frequencies from 3000 to 8000 Hz. This could be due to the changes induced by haemodialysis and duration and severity of disease.

*Stavroulaki P* et al [14] concluded that DPOAEs seem to be more sensitive to incipient cochlear damage than behaviour thresholds in monitoring renal patients .In our study we found that patients with significant change in hearing thresholds as measured by audiometry also showed significant changes in DPOAE amplitudes after 3 and 5 sessions of haemodialysis, furthermore those patients with no significant change in hearing thresholds also showed significant changes in DPOAE amplitudes .Therefore, DPOAEs may be useful in foretelling a substantial threshold shift for a particular frequency prior to a measurable hearing loss. The results of this study indicate that DPOAE is a sensitive tool in ascertaining the insult to the inner ear following haemodialysis even when there are no significant shifts in audiometric thresholds.

## CONCLUSIONS

Great advances have been made in the management of patients on chronic dialysis, so that the life expectancy of these patients has increased dramatically. With increased patient survival and control of renal disease, the side effects on other organs have started coming to light.

In our study we have found that DPOAE is an excellent tool to detect damage to the inner ear following haemodialysis even before these changes are identifiable audiometrically.

Although a definite statement regarding the relationship between haemodialysis and hearing loss would require data from larger samples than those presently used, it seems reasonable to assume that there was a depression in the hearing threshold of patients with CRF following three and five sessions of haemodialysis in our study.

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How to cite this article: Singh SK, Kurkure R, Mokamat S et al. A study to predict hearing loss in patients undergoing hemodialysis by using DPOAE. Int J Res Rev. 2016; 3(2):18-23.


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