The Journal of International Advanced Otology

J Int Adv Otol 2022; 18(2): 131-138 • DOI: 10.5152/iao.2022.21291

Original Article

The Correlation Between Detection Value of Distortion-Product Otoacoustic Emissions and the Early Prognosis of Sudden Sensorineural Hearing Loss

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Cite this article as: Liu S, Shi W, Zheng H, Yuan Y, Li J, Li Q. The correlation between detection value of distortion-product otoacoustic emissions and the early prognosis of sudden sensorineural hearing loss. *J Int Adv Otol* 2022;18(2):131-138.

BACKGROUND: To explore the correlation between the detection value of distortion-product otoacoustic emissions and the early prognosis of sudden sensorineural hearing loss.

METHODS: Seventy-eight patients with first-onset sudden sensorineural hearing loss (all frequencies) from April 2018 to July 2019 were included in this study. Distortion-product otoacoustic emissions and pure-tone audiometry tests were performed at days 0, 3, and 6 of admission. Repeated measures analysis of variance was performed to evaluate the changes in the signal-to-noise ratio for different distortion-product otoacoustic emissions frequencies over time and the interaction of grouping factors and time factors.

RESULTS: The distortion-product otoacoustic emissions evocation rate in the 4 groups was significantly different starting at day 3 of treatment. It was higher in the cured (35.3%) and obviously effective (20.0%) groups than in the other 2 groups (0%, 0%). At the 6 *f*2 frequencies of 1105 Hz, 1560 Hz, 2211 Hz, 3125 Hz, 4416 Hz, and 8837 Hz, the signal-to-noise ratio was different among the groups ($P < .05$) and was notably higher in the cured group. The analysis of the signal-to-noise ratio change before and after treatment at the intermediate *f*2 frequencies of 1105 Hz, 1560 Hz, and 2211 Hz in all patients indicated a linear correlation between the signal-to-noise ratio change and the pure-tone hearing threshold change, with a correlation coefficient of 0.481.

CONCLUSION: Distortion-product otoacoustic emissions evocation in the early stage (within 3 days of treatment) or the signal-to-noise ratio trend over time at intermediate frequencies may predict the prognosis of sudden sensorineural hearing loss.

KEYWORDS: Auditory, distortion-product otoacoustic emission, pure-tone audiometry, sudden sensorineural hearing loss, therapeutic outcome

INTRODUCTION

Sudden sensorineural hearing loss (SSNHL), also known as sudden deafness, is usually defined as a unilateral hearing loss (HL) of at least 30 dB HL in 3 consecutive frequencies in the standard pure-tone audiogram and can present at varying levels of severity from mild to total.[1] Sudden sensorineural hearing loss is an emergency disease requiring immediate diagnosis and treatment. The pathogenesis of SSNHL remains unknown, which influences the preventive and therapeutic strategy-making.[2] In clinical practice, it is not uncommon for cases with similar levels of HL to differ in prognosis. The current research regarding prognostic indicators is controversial. In general, timely consultation, mild HL, age less than 60 years, and no accompanying vertigo and tinnitus lead to good prognosis.[3,4] We have noted in practice that some cured patients displayed early improvement of distortion-product otoacoustic emissions (DPOAE). Given this observation, "can DPOAE be used to predict the early prognosis of sudden sensorineural hearing loss?"

Evoked otoacoustic emissions (OAEs) can be further categorized into DPOAE, transient-evoked OAEs, stimulus-frequency OAEs, and electrically evoked OAEs. As a type of audiometry, DPOAE is probably more comprehensive and sensitive than pure-tone audiometry (PTA) for predicting the early prognosis of SSNHL.[5] Otoacoustic emissions are sound energy generated in the cochlea and released

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Received: April 8, 2021 • **Accepted:** May 26, 2021
Available online at www.advancedotology.org

Table 1. The Basic Conditions of Patients in Different Groups

	Invalid	Effective	Obviously Effective	Cured	Sum	Statistics	*P*
	(n=27)	(n=14)	(n=20)	(n=17)	(n=78)		
Gender							
Male	13 (48.1%)	8 (57.1%)	12 (60.0%)	6 (35.3%)	39 (50.0%)	$\chi^2=2.593$	.459
Female	14 (51.9%)	6 (42.9%)	8 (40.0%)	11 (64.7%)	39 (50.0%)		
Age	46.5 ± 15.9	43.0 ± 18.4	38.8 ± 14.0	38.8 ± 14.8		$F=1.266$	.292
Type of SSNHL							
Flat	16 (59.3%)	7 (50.0%)	9 (45.0%)	13 (76.5%)	45 (57.7%)	$\chi^2=4.143$	.246
Total deafness	11 (40.7%)	7 (50.0%)	11 (55.0%)	4 (23.5%)	33 (42.3%)		
Pure-tone threshold (dB)	79.9 ± 28.0	78.0 ± 25.0	84.2 ± 17.7	63.0 ± 21.6		$F=16.206$	0

into the external auditory canal through the ossicular chain and tympanic membrane in a process that is the reverse of an afferent sound wave; they reflect the activity of the cochlear mechanism[6] and provide an objective basis for detecting cochlear lesions.[7] Reports have been published on the change in acoustic emissions after the onset of or during the course of treatment for SSNHL; however, there are some studies regarding the use of OAEs to predict SSNHL therapeutic outcomes,[8-11] but there is no distinction between the types of SSNHL, such as high-frequency drop, low-frequency drop, and full-frequency drop. Compared with other types of OAEs, DPOAE has the advantages of frequency specificity, amplitude, and a wide dynamic range that best reflects the frequency characteristics of cochlear HL.[12] Therefore, this study aims to explore the relationship between early changes in DPOAE and the prognosis of SSNHL at full frequency by dynamically detecting DPOAE.

MATERIALS AND METHODS

Clinical Data

The patients diagnosed with SSNHL at all frequencies in our hospital from April 2018 to July 2019 were enrolled in this study. There are 78 patients with SSNHL, and we usually do not admit SSNHL patients with low-frequency drop and high-frequency drop. They were divided into invalid (n=27), effective (n=14), obviously effective (n=20), and cured (n=17) groups according to the hearing recovery rates at discharge. The basic conditions of patients in different groups are shown in Table 1.

Inclusion criteria were as follows: (1) diagnosis of SSNHL and the classification of HL types should be in accordance with the Chinese Medical Association guidelines[13]; (2) Should include all frequencies SSNHL including flat-type HL and complete deafness; flat-type is defined as HL at all frequencies and the average pure-tone threshold of 250-8000 Hz (250 Hz, 500 Hz, 1000 Hz, 2000 Hz, 4000 Hz, and 8000 Hz) is ≦80 dB HL; complete deafness is defined as HL at all frequencies and the average pure-tone threshold of 250-8000 Hz (250 Hz, 500 Hz, 1000 Hz, 2000 Hz, 4000 Hz, and 8000 Hz) is ≥81 dB HL; (3) Should have unilateral HL; (4) the duration from onset to admission should be within 13 days and untreated before admission.

Exclusion criteria included: (1) children and patients with recurrent sudden deafness, pregnancy, and middle ear infection; (2) if the cause of HL was confirmed; (3) if one has absolute contraindications for glucocorticoids, such as digestive tract ulcer, active hepatitis, and uncontrolled tuberculosis.

Distortion-product otoacoustic emissions and PTA were performed on days 0 (before admission), 3, and 6. During hospitalization, all patients included in the study were combined with drugs in accordance with the guidelines of the Chinese Medical Association[13]: (1) methylprednisolone 40 mg was injected behind the ear into the subperiosteum, once every other day, 5 times in total; (2) batroxobin 10 Bu for the first time, 5 Bu each time, a total of 3 times once every other day; check fibrinogen before each use, if it is less than 1g/L, pause; and (3) ginkgo biloba extract was taken orally, 40 mg once, and 3 times a day; (4) adjuvant hyperbaric oxygen therapy is started for patients whose onset time is more than 1 week after admission, once a day, 6 times a week. The therapeutic outcome was evaluated by comparing the first PTA with the last PTA before discharge according to the standards of the Chinese Medical Association. The criteria for the assessment of hearing recovery[13] are as follows: (1) cured: all the thresholds of 250-4000 Hz of patients could recover to the hearing level of normal people, or to the same threshold level as the contralateral ear, or to the hearing level before onset; (2) obviously

MAIN POINTS

- The type of hearing loss in all patients we included in the study was full-frequency descent. We performed both distortion-product otoacoustic emissions (DPOAE) and pure-tone audiometry (PTA) at days 0, 3, and 6 of admission and analyzed the therapeutic outcome of SSNHL at all frequencies. At present, there is not much research in this area.
- Excluding the interference of low-frequency and high-frequency degrading hearing loss types, we found that the signal-to-noise ratio value of the cured group and the obviously effective group increased significantly at 0, 3, and 6 days, which changes in the same trend as the PTA curve.
- Compared with the hearing level of PTA, the intermediate frequency (1105 Hz, 1560 Hz, 2211 Hz, 3125 Hz, and 4416 Hz) early changes of DPOAE (within 3 days of intervention) in patients with SSNHL can better reflect the function of cochlear out hairs, which can well predict the prognosis of SSNHL. This could increase the confidence of doctors and patients in adhering to treatment.

effective: patients in whom the average hearing gain of the above frequencies is more than 30 dB; (3) effective: patients in whom the average hearing gain of the above frequencies is 15-30 dB; and (4) invalid: patients in whom the average hearing gain is less than 15 dB.

The DPOAE equipment used in the study was the SmartOAE diagnostic model (Sn:IHS6482, Intelligent Hearing Systems, USA), with an initial stimulus frequency of $f2 : f1 = 1.22$ and an initial stimulus intensity of $L1/L2 = 65/55$ (dB SPL). $f1$ frequencies of 455, 641, 905, 1281, 1810, 2563, 3619, 5121, and 7243 Hz, $f2$ frequencies of 553, 783, 1105, 1560, 2211, 3125, 4416, 6250, and 8837 Hz, and $2f1-f2$ frequencies of 357, 499, 704, 1003, 1409, 2000, 2822, 3991, and 5649 Hz were applied and were stacked 16 times. Six dB SPL above the noise floor was the standard used to confirm the occurrence of the response.[8] Six responses out of 9 frequencies were considered to indicate successful evocation; otherwise, DPOAE was considered unevoked.[5,9] The pure-tone audiometric instrument used was a GSI AudioStar Pro Clinical Audiometer (Sn:GS0065702, GSI Grason-Stadler, USA) with test frequencies of 0.25, 0.5, 1, 2, 4, and 8 KHz. The test was performed in a sound-proof room with background noise less than 30 dB(A) in line with the national standards.[14] The DPOAE and audiometric instruments were calibrated before the study.

Statistical Analysis

The clinical data of 78 SSNHL cases was analyzed retrospectively. The statistical analysis was performed by using Statistical Package for the Social Sciences software 22.0 (IBM SPSS Corp.; Armonk, NY, USA). Measurement data with a normal distribution are presented as mean ± standard deviation. The difference in the composition ratios and rates between groups was measured by the likelihood ratio chi-square test. One-way analysis of variance (ANOVA) was used to compare the means between groups. The difference in repeated measures data between groups was calculated by repeated measures ANOVA. Correlation between 2 indicators within the same patient was determined using Pearson's correlation analysis.

RESULTS

The time from onset to the start of treatment was 1-13(5.04±3.18) days, and hospitalization lasted 7-10 (8.72 ± 1.17) days. χ^2 values were derived by likelihood ratio chi-square test; F values were derived by ANOVA, $P < .05$.

Significant differences in DPOAE evocation started to occur at day 3 of treatment ($\chi^2 = 17.65$, $P = .001$) and at day 6 of treatment ($\chi^2 = 30.018$, $P = .000$). The rates were higher in the cured and obviously effective groups than in the other 2 groups (Figure 1).

Repeated measures ANOVA was performed to evaluate the changes in the signal-to-noise ratio (SNR) for different DPOAE frequencies over time as well as for the interaction of grouping factors and time factors. In the cured group, SNR was increased over time at the intermediate $f2$ frequencies of 1105, 1560, 2211, 3125, and 4416 Hz, $P < .05$. In the obviously effective group, SNR also was increased over time at the intermediate $f2$ frequencies of 1105 and 2211 Hz, $P < .05$ and a trend toward an increase at the $f2$ frequency of 1560 Hz, $P > .05$ was observed (Table 2).

The changing curve of SNR and pure-tone HL before the treatment and during the treatment shows that hearing recovery is closed related to the evocation of DPOAE (Figure 2).

The SNR values were significantly different between groups at the $f2$ frequencies of 1105 Hz, 1560 Hz, 2211 Hz, 3125 Hz, 4416 Hz, and 8837 Hz ($P < .05$). With the exception of $f2$ −8837 Hz, the SNR for the other 5 frequencies changed significantly over time (days 0, 3, and 6) in the cured group, displaying a linear increasing trend. The SNR for the frequencies of 1105 Hz and 2211 Hz exhibited a linear increasing trend in the obviously effective group ($P < .05$). The SNR for $f2$−1560 Hz also increased gradually in the obviously effective group, though the P-value was greater than .05. The other 2 groups did not show any obvious linear trends (Figure 3).

Scatter plots were drawn for the change in PTA (500 Hz, 1000 Hz, 2000 Hz, and 4000 Hz) and the change in SNR for 3 positive DPOAE frequencies ($f2$−1105 Hz, $f2$−1560 Hz, and $f2$−2211 Hz) in 78 patients before and after treatment. A linear correlation between the 2 factors was noted. Pearson's correlation analysis further confirmed that the correlation coefficient was 0.481, with a P-value of .000 (Figure 4).

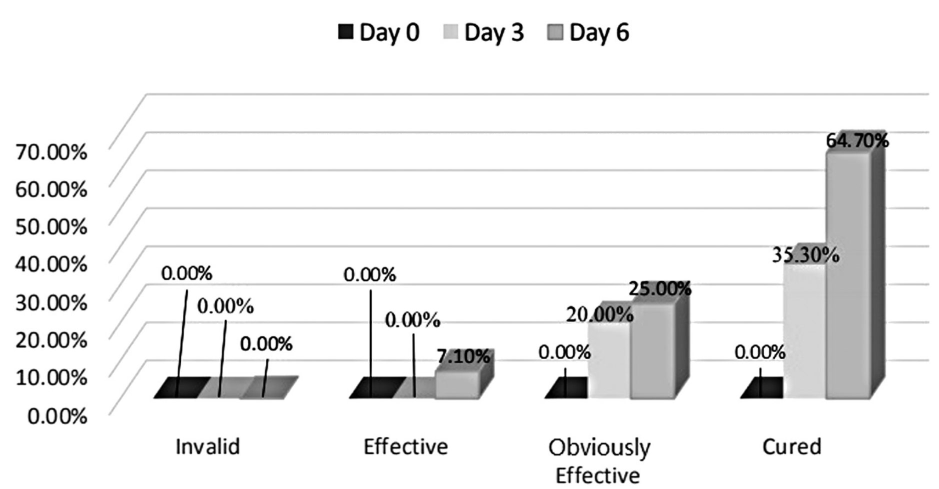

Figure 1. The evocation rates of DPOAE at days 0, 3, and 6 in different groups. DPOAE, distortion-product otoacoustic emission.

Table 2. The Trend Over Time in SNR for All DPOAE Frequencies for Different Groups

*f*2 Frequency and Group	Zero Day	Third Day	Sixth Day	Time		Group		Time × Group	
				F	*P*	*F*	*P*	*F*	*P*
553 Hz									
Invalid	1.2 ± 5.3	1.9 ± 4.5	-2.6 ± 5.7	5.858	.005	0.184	.91	1.384	.254
Effective	−0.1 ± 3.7	0.6 ± 6.7	1.0 ± 6.5	0.111	.895				
Obviously effective	0.2 ± 6.2	0.5 ± 5.5	0.7 ± 6.9	0.035	.965				
Cured	0.3 ± 5.0	0.4 ± 5.3	2.7 ± 6.0	1.256	.298				
783 Hz									
Invalid	0.6 ± 6.5	0.4 ± 5.5	−0.2 ± 6.7	0.133	.875	0.686	.56	1.137	.34
Effective	3.5 ± 4.9	0.9 ± 5.1	−0.3 ± 11.9	1.142	.316				
Obviously Effective	−1.8 ± 5.8	1.6 ± 4.7	1.8 ± 5.4	4.075	.025				
Cured	0.4 ± 5.7	1.2 ± 7.5	5.1 ± 8.7	3.123	.058				
1105 Hz									
Invalid	5.6 ± 1.1	1.3 ± 3.8	−0.2 ± 5.4	0.817	.41	8.316	0	1.651	.185
Effective	2.8 ± 8.2	2.7 ± 7.0	3.2 ± 10.3	0.017	.983				
Obviously effective	−0.7 ± 5.2	1.2 ± 7.2	8.1 ± 9.6	9.092	.001				
Cured	5.6 ± 6.6	7.2 ± 11.2	13.8 ± 8.6	8.331	.001				
1560 Hz									
Invalid	1.8 ± 5.5	1.4 ± 5.0	0.1 ± 6.9	1.089	.344	10.81	0	0.331	.803
Effective	1.0 ± 8.6	4.7 ± 9.6	4.8 ± 10.9	1.202	.317				
Obviously effective	1.8 ± 7.5	4.6 ± 8.3	7.5 ± 10.3	2.52	.094				
Cured	4.5 ± 10.2	11.8 ± 12.2	19.9 ± 8.7	14.182	0				
2211 Hz									
Invalid	3.4 ± 5.0	4.3 ± 4.6	1.9 ± 6.2	1.793	.177	10.54	0	0.481	.697
Effective	4.3 ± 8.8	3.2 ± 8.4	2.8 ± 11.6	0.179	.838				
Obviously effective	1.3 ± 6.5	6.1 ± 6.1	8.8 ± 8.4	7.2	.009				
Cured	6.5 ± 9.7	14.1 ± 11.5	18.5 ± 8.1	15.989	0				
3125 Hz									
Invalid	1.3 ± 6.2	3.4 ± 6.7	4.4 ± 4.6	2.323	.108	10.28	0	5.876	.001
Effective	4.4 ± 7.7	−4.4 ± 11.7	3.50 ± 8.8	3.771	.036				
Obviously effective	2.7 ± 7.8	4.2 ± 6.9	3.5 ± 7.3	0.257	.775				
Cured	5.6 ± 9.0	12.5 ± 9.8	13.9 ± 11.8	4.149	.025				
4416 Hz									
Invalid	0.8 ± 6.5	3.0 ± 5.2	3.0 ± 4.7	2.405	.1	3.435	.02	1.376	.257
Effective	5.6 ± 8.8	2.0 ± 7.5	4.2 ± 7.5	1.128	.325				
Obviously effective	2.4 ± 6.0	1.9 ± 6.0	−0.9 ± 12.8	0.861	.431				
Cured	2.0 ± 7.0	7.2 ± 10.8	11.2 ± 9.5	7.973	.002				
6250 Hz									
Invalid	4.8 ± 4.4	4.1 ± 5.1	2.3 ± 6.1	1.914	.167	1.748	.17	0.129	.942
Effective	3.0 ± 7.5	2.9 ± 7.0	2.3 ± 6.0	0.086	.918				
Obviously effective	3.1 ± 5.0	2.8 ± 7.67	3.0 ± 5.9	0.015	.985				
Cured	4.5 ± 4.4	7.2 ± 12.1	7.88 ± 12.7	0.907	.414				
8837 Hz									
Invalid	5.4 ± 7.7	4.8 ± 6.8	4.0 ± 7.4	0.458	.635	3.399	.02	0.859	.466
Effective	3.5 ± 10.7	3.9 ± 5.3	2.7 ± 4.8	0.129	.797				
Obviously effective	4.8 ± 7.7	4.4 ± 7.8	6.1 ± 7.9	0.389	.68				
Cured	8.5 ± 7.6	11.0 ± 9.8	8.9 ± 11.0	0.419	.59				

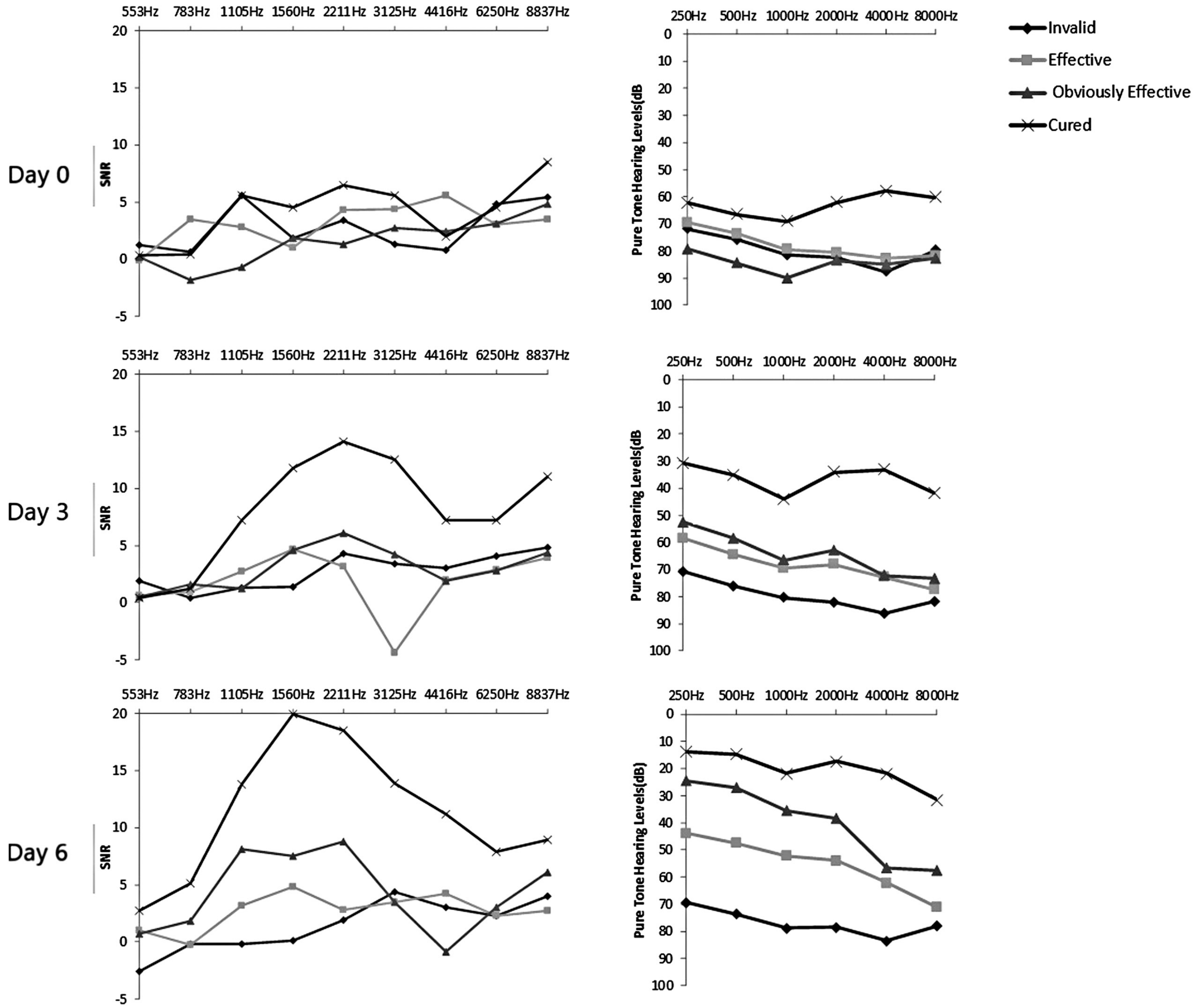

Figure 2. The trend over time in SNR for all DPOAE frequencies and the result of PTA for different groups. DPOAE, distortion-product otoacoustic emission; SNR, signal-to-noise ratio; PTA, pure-tone audiometry.

DISCUSSION

Otoacoustic emissions are caused by the nonlinear, micromechanical movement of cochlear outer hair cells.[15] Otoacoustic emissions can be broadly classified into spontaneous OAEs and evoked otoacoustic emissions, depending on whether there is external stimulus. A study has demonstrated that DPOAE is more sensitive than PTA for cochlear function[16] and their frequency characteristics are typical and are very similar to the frequency range of PTA.[17] Otoacoustic emission testing is fast, highly repeatable, and stable. Therefore, the use of OAE to evaluate the prognosis of SSNHL has a solid theoretical basis and practical support. With treatment for SSNHL, the function of the cochlear hair cells is gradually restored, and DPOAE may begin to increase from weak to strong.[18]

Recent research shows that hearing improvement on days 3-4 and 6-7 after treatment imitation was analyzed as potential prognostics factors.[19] There are some reports about the use of DPOAE in evaluating the prognosis of SSNHL. Ting-Kuang Chao[8] performed DPOAE every day for 7 days on 108 hospitalized patients with SSNHL and concluded that the increase in the average DPOAEs amplitude was a good prognostic factor for hearing recovery. They used the most updated information on DPOAE at 3 days or more before the recovery in the analysis, but their purpose is not to evaluate the effect of treatment.

Compared with this study, we not only performed DPOAE and PTA at days 0, 3 , and 6 of admission but also analyzed the therapeutic outcome of SSNHL at all frequencies.[8] HongJu Park's[11] study of 40 patients with SSNHL found that the initial sum of DPOAEs was significantly decreased in patients with moderately severe to profound SSNHL (average hearing threshold ≤55 dB) and that the change in the sum of DPOAE at 2 weeks was closely correlated with hearing threshold improvement. However, the initial DPOAE sum was not changed in patients with mild to moderate SSNHL, and the change in the sum of the DPOAE at 2 weeks was not correlated with hearing threshold improvement.[11] Takanori Mori[10] investigated 78 patients

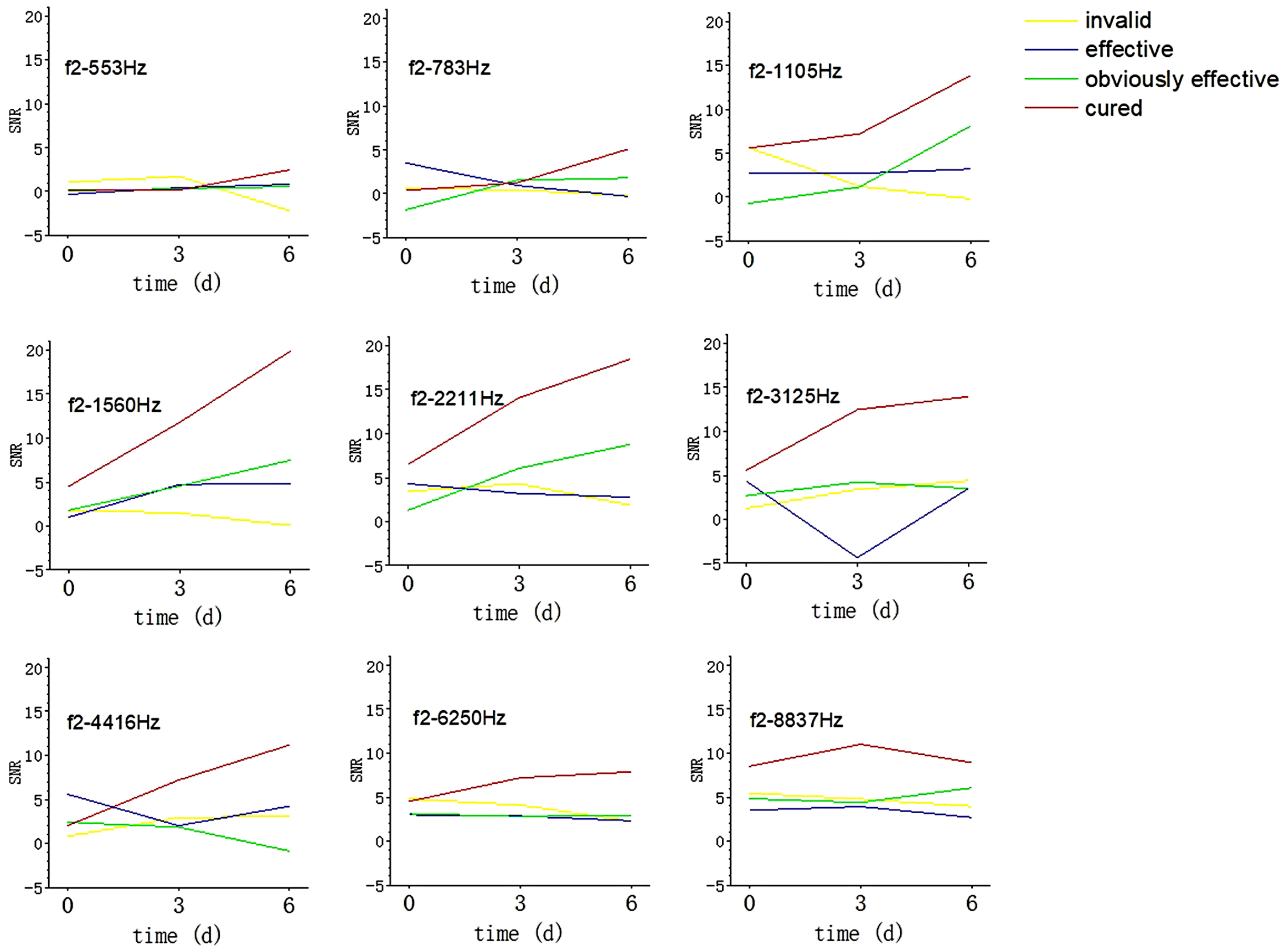

Figure 3. The interaction profile of time and grouping for SNR at all DPOAE frequencies. DPOAE, distortion-product otoacoustic emission; SNR, signal-to-noise ratio.

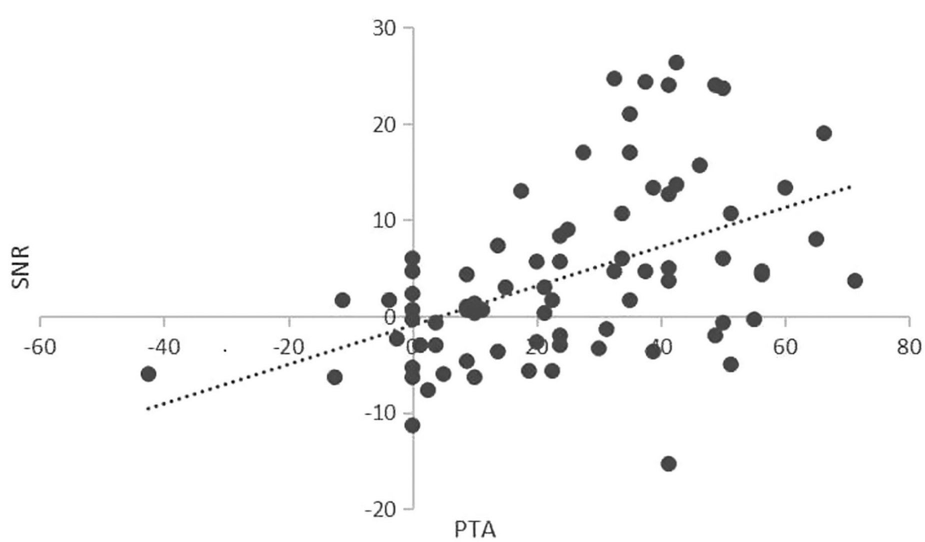

Figure 4. The correlation between the average SNR change at the 3 intermediate frequencies and the pure-tone threshold change.

with SSNHL and observed that the net DPOAE amplitude in patients with a hearing improvement rate ≥50% was significantly higher than that of patients with a hearing improvement rate <50% at the *f*2 frequencies of 3031 and 4812 Hz; moreover, the hearing improvement rate at 1 month was linearly correlated with the SNR of the initial DPOAE at these 2 frequencies. In a study of 15 patients with SSNHL, Avi Shupak[9] concluded that whether DPOAE could be evoked was a predictor of the hearing improvement rate at 3 months and had a sensitivity of 71% and a specificity of 100%.

Although many scholars have reported on the use of DPOAE as a predictor of therapeutic outcomes in SSNHL, different types of SSNHL were not mentioned in these studies. In the Chinese Medical Association guidelines,[13] SSNHL is divided into 4 types and each type has a distinct etiology: low-frequency drop type may be caused by labyrinthine hydrops, high-frequency drop type by hair cell damage, flat-type by dysfunction of the stria vascularis or vasospasm of the inner ear, and complete deafness may be by inner ear embolism or thrombosis. Because of the possible differences in pathogenesis, there may be differences in the consequences of DPOAE. Multicenter research shows that low-frequency drop type has the best therapeutic outcome, followed by flat HL, whereas the outcomes of high-frequency drop type and complete deafness are poor.[20] In patients with sudden low-frequency or high-frequency sensorineural HL, the hair cells of certain frequencies are damaged, while the function and DPOAE of hair cells of other frequencies may still be normal. Hong Ju Park et al[11] found no change in initial DPOAE in patients with mild to moderate SSNHL (average hearing threshold ≤55 dB), probably because patients with low-frequency and high-frequency SSNHL were combined, creating a confounding factor that interfered with the study results. The strict inclusion criteria eliminate interference from different types of SSNHL, thereby better reflecting the value of DPOAE for predicting the therapeutic outcomes of SSNHL at all frequencies.

Our findings have shown that DPOAE at intermediate frequencies can be a valuable predictor of the prognosis on SSNHL. In Table 2, patients in the cured group had an increase in SNR over time at the intermediate *f*2 frequencies of 1105 Hz, 1560 Hz, 2211 Hz, 3125 Hz, and 4416 Hz, whereas there was no obvious SNR change in the low (<1000 Hz) and high (>6000 Hz) *f*2 frequencies. Patients in the obviously effective group also showed an increase in SNR over time at the intermediate *f*2 frequencies of 1105 Hz and 2211 Hz and a trend toward an increase at the *f*2 frequency of 1560 Hz, though there is no statistical significance of the latter ($P > .05$). Similarly, there was also no obvious SNR change at the low (<1000 Hz) and high (>3000 Hz) *f*2 frequencies in the obviously effective group. The effective and invalid groups had no obvious SNR change at any frequency. And in Figure 2, the changing curve of PTA at days 0, 3, and 6 also shows that the improvement of SNR coincided with the change of PTA. Therefore, SNR changes in DPOAE at intermediate frequencies seem to be associated with the therapeutic outcomes of SSNHL and may better reflect the functional recovery of outer hair cells than the SNR at low and high frequencies which was compatible with previous findings.[21,22] This phenomenon may be related to the fact that low frequencies are usually affected by body noise and ambient noise and have a lower rate of evoking DPOAE than intermediate frequencies; high frequencies also have a lower rate of evoking DPOAE as the high-frequency zone of PTA and the corresponding outer hair cells are very difficult to recover in cases of SSNHL.[4,13] We further divided the patients into invalid, effective, obviously effective, and cured groups based on the different rates of hearing recovery. The early DPOAE change was compared among the groups, an evaluation that has never been reported in previous literature. Significant differences in the DPOAE evocation rate among the groups started to occur at day 3 of the intervention. As shown in Figure 1, groups with better outcomes had higher DPOAE evocation rates: the fully cured (35.3%) and obviously effective (20.0%) groups had DPOAE results that were significantly higher than those of the effective (0%) and invalid (0%) groups. At day 6, the DPOAE evocation rate was further increased in the cured group (64.7%) but was only minimally changed in the other groups. Although the hearing of all patients in the cured group recovered within 10 days of hospitalization, 35.5% of this group failed to evoke DPOAE at day 6, suggesting that negative prediction should not be drawn too early and that treatment and dynamic re-examination should be continued. Figure 3 exhibits the variation of SNR values between groups. The cured group exhibited a linear increase in SNR over time at the *f*2 frequencies of 1105 Hz, 1560 Hz, 2211 Hz, 3125 Hz, and 4416 Hz in DPOAE. Similar SNR changes occurred in the obviously effective group but only at the intermediate *f*2 frequencies of 1105 Hz, 1560 Hz, and 2211 Hz. A linear increasing trend was not observed in the effective and invalid groups. Figure 4 provides the scatter plots to show that the change in intermediate DPOAE frequencies (*f*2 −1105 Hz, 1560 Hz, and 2211 Hz) was linearly correlated with the change in PTA.

CONCLUSION

Successful DPOAE evocation at an early stage (within 3 days of intervention) or a linear increase in the SNR over time at intermediate DPOAE frequencies suggests a better early prognosis or even the possibility of cure. Thus, we recommend active interventions for these patients. Compared with previous literature, we have examined the interference of different types of SSNHL in this study and will further increase the sample size and explore flat-type HL and complete deafness separately in future studies. After that, we also need to group the patients with full-frequency SSNHL based on the presence or absence of accompanying symptoms and observe the relationship between their changes in DPOAE and the early prognosis of SSNHL.

Ethics Committee Approval: The study has been approved by the Medical Ethics Committee of the Southern Medical University. The ethical code is NFEC-202002-K4-01.

Informed Consent: N/A.

Peer-review: Externally peer-reviewed.

Author Contributions: Concept – S.-Y.L., W.-Y.S.,H.-Y.Z., J.-J.L., Q.L.; Design – S.-Y.L., W.-Y.S., Y.-X.Y., J.-J.L., Q.L.; Supervision – S.-Y.L., W.-Y.S., H.-Y.Z., J.-J.L., Q.L.; Resources – S.-Y.L.; Materials – W.-Y.S.; Data Collection and/or Processing – S.-Y.L., W.-Y.S., H.-Y.Z., J.-J.L.; Analysis and/or Interpretation – S.-Y.L., W.-Y.S., J.-J.L.; Literature Search – W.-Y.S.; Writing Manuscript – S.-Y.L.; Critical Review – J.-J.L., Q.L.

Acknowledgments: The authors would like to thank all the individuals who participated in this study. They are grateful to audiologist S Shimoara from the Miyazaki University and T. Yuji of University of Miyazaki for their assistance in this study.

Declaration of Interests: The authors have no conflict of interest to declare.

Funding: Natural Science Foundation of Guangdong Province (2021A1515010957); Dean's Fund of Southern Hospital, Southern Medical University of Guangdong Province (2019B011).

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