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# Treatment of Long-term Sudden Sensorineural Hearing Loss as an Otologic Migraine Phenomenon

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**Objectives:** To describe a cohort of patients presenting with long-term sudden sensorineural hearing loss (SSNHL) treated with prophylactic migraine and intratympanic steroid therapy.

**Methods:** Patients presenting to a neurotology clinic at least 6 weeks from SSNHL onset were included. All patients received migraine prophylactic medication (nortriptyline, topiramate, and/or verapamil) and lifestyle changes for at least 6 weeks, as well as intratympanic steroid injections, if appropriate.

**Results:** Twenty-one patients (43% female) with a mean age of  $64 \pm 11$  years who presented  $9 \pm 8$  months (median = 5) from symptom onset were included. Posttreatment hearing thresholds were significantly improved compared with pretreatment thresholds at 500 Hz ( $49 \pm 19$  dB versus  $55 \pm 20$  dB,  $p = 0.01$ ), 1000 Hz ( $52 \pm 19$  dB versus  $57 \pm 21$  dB,  $p = 0.03$ ), low-frequency pure-tone average ( $53 \pm 15$  dB versus  $57 \pm 17$  dB,  $p = 0.01$ ), and speech-frequency pure-tone average ( $57 \pm 13$  dB versus  $60 \pm 15$  dB,  $p = 0.02$ ). Posttreatment word-recognition-score (WRS) and speech-recognition-threshold (SRT) were also significantly

improved ( $45 \pm 28\%$  versus  $70 \pm 28\%$  and  $57 \pm 18$  dB versus  $50 \pm 16$  dB, respectively, both  $p < 0.01$ ). Notably,  $\geq 15\%$  improvement in WRS and  $\geq 10$  dB improvement in SRT was observed in 13 (68%) and 8 (40%) patients, respectively. Of the 11 patients who presented with initial  $< 50\%$  WRS, 8 (73%) had improved posttreatment  $> 50\%$  WRS with an average improvement of  $39 \pm 9\%$ .

**Conclusions:** Migraine medications in addition to intratympanic steroid injections significantly improved SRT and hearing frequencies in 40% and 29% of SSNHL patients, respectively, while significant WRS recovery was observed in most (68%) patients. This suggests SSNHL may be an otologic migraine phenomenon, which may be at least partially reversible even after the traditional 30-day postonset window. **Key Words:** Chronic hearing loss—Long-term hearing loss—Migraine—Otologic migraine—Sudden sensorineural hearing loss—Word recognition score.

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With an annual incidence of 27 per 100,000 US adults (1), sudden sensorineural hearing loss (SSNHL) can result in functional decline and poor quality of life (2). The US National Institute for Deafness and Communication Disorders defines SSNHL as a  $\geq 30$  dB reduction in  $\geq 3$  contiguous audiometric frequencies occurring within 3 days (3). It has been previously shown that up to one- to two-thirds of SSNHL patients can experience

spontaneous recovery of hearing loss (4,5). Factors predictive of a worse prognosis may include a higher degree of hearing loss at initial presentation, the absence of steroid therapy, abnormal caloric testing, contralateral hearing impairment, and previous hearing loss or association with disorders of the vestibular system (6–8). Additionally, prompt treatment following the initial onset of SSNHL symptoms is another important prognostic factor (8–10). Although there exist a variety of treatment approaches for SSNHL such as oral and intratympanic (IT) steroids, there is currently no consensus on a standard-of-care or efficacious management (5,11). There also exists a paucity of research on treating patients without spontaneous recovery who neither receive nor respond to early treatment. It has been suggested that treatment needs to occur within 2 to 4 weeks for efficacy (11,12). As such, most patients who present after this time period are not offered any additional treatment options and continue to suffer from hearing loss. This warrants the investigation of novel treatments for long-term SSNHL for patients who did not seek immediate

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medical attention or were nonresponsive to initial treatment.

The etiology of SSNHL is yet to be fully understood, but several studies have suggested its association with vascular impairments of the cochlea (13,14). Migraine is another complex disorder that is also suggested to be at least partially vascular in nature (15), and its higher prevalence among SSNHL patients has been demonstrated (16,17). Our group recently showed that SSNHL recovery was improved when oral and IT steroid therapies were supplemented with adjuvant migraine treatment (18). Herein, this retrospective and uncontrolled study reports our institution's experience with long-term SSNHL patients presenting at least 6 weeks after initial symptomatic onset, managed as an otologic migraine phenomenon with comprehensive migraine treatment.

## METHODS

With Institutional Review Board approval, a retrospective chart review of patients presenting to our tertiary-care neurotology clinic from February 2017 to March 2020 was performed. SSNHL was defined as  $\geq 30$  dB reduction in  $\geq 3$  contiguous audiometric frequencies occurring within 3 days and diagnosed by the senior author. Initial audiograms for all but three patients were obtained at the authors' home institution. Long-term SSNHL was defined as presenting with a chief complaint of SSNHL at least 6 weeks after the onset of the hearing loss. This included those who did not seek prompt ( $< 6$  wks) treatment, and those who sought previous treatment but did not experience improvements. Patients who received previous treatments (i.e., steroid therapy) with hearing improvement were excluded. Patients who reported recent direct or sound trauma, or those with a history of Menière's disease or fluctuating hearing loss were also excluded. Those already receiving medications for migraine management were excluded.

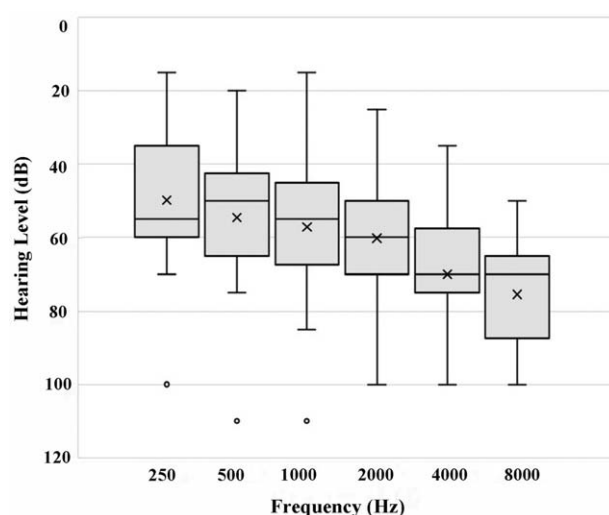
All included long-term SSNHL patients were offered adjuvant migraine prophylactic medications and lifestyle modifications, as well as IT steroid injections (dexamethasone 10 mg/ml placed in the anterior superior quadrant with oral suctioning for 30 min) if the patient did not improve to their baseline after reaching the maximum tolerable dosage of the migraine medications. A minimum of two injections were given on a twice-a-week regimen unless the patient refused the second injection. If the patient had improvement in thresholds ( $\geq 10$  dB in two frequencies) or word recognition score (WRS) after two injections, then more IT injections were given until there was no improvement. Migraine prophylactic medications included nortriptyline, topiramate, and/or verapamil. Dosage was escalated gradually every 1 to 2 weeks, with the maximum allowed dosage for nortriptyline, topiramate, and verapamil being 75, 150, and 240 mg, respectively. Dosages were titrated based on side effects and vital signs until symptomatic improvement was achieved. Patients were moved up on medication doses to the maximum dosages (nortriptyline 75 mg and topiramate 150 mg) and seen at the 6-week time point. At 6 weeks, the patients had been on topiramate 150 mg for 1 week and on nortriptyline 75 mg for 2 weeks. Medication adherence was evaluated on each follow-up visit, and migraine medications were tapered off 4 to 8 weeks after reaching maximum dosage. If there was no improvement and the patient did not want to receive IT steroid injections, the medications were tapered off. If the patient opted

to receive IT steroid injections, the medications were tapered after the last IT steroid injection. In addition to medication, as part of a comprehensive migraine prophylactic regimen, patients were also strongly advised on migraine lifestyle modifications. This included dietary recommendations (e.g., avoiding food preservatives, fermented products, alcohol, chocolate, processed meat, etc.), supplementations (magnesium 400 mg orally twice a day and riboflavin 200 mg orally twice a day), and regular sleep and meal schedules.

All included patients had normal magnetic resonance imaging, tympanometry at 226 Hz, and microscopic examination. Chart reviews of all patient visits were performed to evaluate for clinical history, assessments, treatments, and patient-reported hearing quality and medication compliance. Comprehensive audiologic testing for each patient was extracted for analysis, including pure-tone average (PTA), speech recognition threshold (SRT), and WRS measured in accordance with the American Academy of Otolaryngology-Head and Neck Surgery guidelines (19). Low-frequency PTA included hearing thresholds at 500, 1000, and 2000 Hz, while speech-frequency PTA included hearing thresholds at 500, 1000, 2000, and 4000 Hz. Posttreatment audiometry evaluation was defined as the final visit's audiometric results and varied among patients. Pre- and posttreatment WRS was not analyzed for 2 (10%) patients due to their language barriers. Pre- and posttreatment SRT was not analyzed for 1 (5%) patient due to lack of pretreatment SRT availability for that patient. As such, the calculated percentage of patients with WRS and SRT improvements use 19 and 20, respectively, as the denominator values. In addition to analyzing average improvement in the various hearing parameters, we also identified patients who had  $\geq 10$  dB improvements in PTA, SRT, and audiometric frequencies, and  $\geq 15\%$  improvement in WRS, to further designate patients with clinically significant hearing improvements according to set thresholds. In the case of bilateral hearing loss, audiometric data for the affected ear was followed. Migraine diagnosis in accordance with the International Classification of Headache Disorders 3rd edition (ICHD-3) beta criteria was assessed for each patient via a comprehensive questionnaire completed at the initial visit. Paired samples *t* test was used to compare pre- and posttreatment audiometric data, while  $\chi^2$  tests were performed to analyze categorical variables. Statistical analyses were performed using SPSS 18.0 software (SPSS Inc., Chicago, IL) and a *p* value  $< 0.05$  was considered significant.

## RESULTS

A total of 21 patients (43% female) with a mean age of  $64 \pm 11$  years (range: 36–81, median: 67) were included. On average, patients presented  $9 \pm 8$  months (range: 2–36, median: 5) from the onset of SSNHL. Common past medical histories included migraine headache ( $n = 17$ , 81%) and previous lifetime history of vertigo ( $n = 15$ , 71%). Of note, the cohort had not experienced vertigo in the preceding 6 months, and the only signs of active migraine in the cohort were neck stiffness or aural pressure. In the cohort, 13 (62%) had tinnitus and 12 (57%) had aural fullness. The distribution of baseline audiograms is demonstrated in Figure 1. All patients received migraine medications for at least 6 weeks, while 15 subjects (71%) also received IT steroid injections (usually given toward the end of the treatment period



**FIG. 1.** Distribution of baseline audiograms in the cohort. Within each box, the horizontal line and  $\times$  mark represent the median and mean, respectively. The box sizes correspond to the 25th to 75th percentile (1st–3rd quartile), and the whiskers represent the full range, excluding the outliers. Represented by a circle, outliers were defined as data exceeding 1.5 times the interquartile range below the 1st quartile or above the 3rd quartile.

if they did not experience hearing restoration back to near baseline). Individual patient presentations and treatment approaches are outlined in Table 1.

Pre- and posttreatment audiometric thresholds are compared in Table 2. Notably, posttreatment hearing thresholds significantly improved compared with pretreatment values at 500 Hz ( $49 \pm 19$  dB versus  $55 \pm 20$  dB,  $p = 0.01$ ), 1000 Hz ( $52 \pm 19$  dB versus  $57 \pm 21$  dB,  $p = 0.03$ ), low-frequency PTA ( $53 \pm 15$  dB versus  $57 \pm 17$  dB,  $p = 0.01$ ), and speech-frequency PTA ( $57 \pm 13$  dB versus  $60 \pm 15$  dB,  $p = 0.02$ ). Mean WRS was significantly improved from pretreatment to posttreatment ( $45 \pm 28\%$  versus  $70 \pm 28\%$ ,  $p < 0.01$ ). Likewise, mean SRT was significantly improved from pretreatment to posttreatment ( $57 \pm 18$  dB versus  $50 \pm 16$  dB,  $p = 0.01$ ). Schematic diagrams of speech-frequency PTA and WRS hearing results, in accordance with standardized audiologic reporting formats (19), are represented in Figure 2. Pre- to posttreatment audiogram changes among all patients and the subcohort with  $\geq 10$  dB improvement in at least two audiometric frequencies ( $n = 6$ , 29%) are demonstrated in Figure 3. The figure shows that, especially in the latter group, posttreatment improvement was more predominant in lower-frequency hearing than high-frequency hearing.

In the overall cohort, the average change in WRS and SRT was  $26 \pm 17\%$  and  $7 \pm 12$  dB, respectively. Moreover, the cohort's mean change in low- and speech-frequency PTA was  $4 \pm 6$  dB and  $3 \pm 6$  dB, respectively. Clinically significant changes in WRS, SRT, PTA, and hearing thresholds are summarized in Table 3. Notably,  $\geq 15\%$  improvement in WRS and  $\geq 10$  dB improvement in SRT was observed in 13 (68%) and 8 (40%) patients,

respectively. Within the subcohort with clinically significant ( $\geq 15\%$ ) WRS improvement, mean WRS change was  $36 \pm 10\%$ . Furthermore, within the subcohort with clinically significant SRT improvement ( $\geq 10$  dB), mean SRT change was  $20 \pm 8$  dB. Six (29%) and three (14%) subjects experienced  $\geq 10$  dB improvement in at least two or three audiometric frequencies, respectively. The 29% of subjects with  $\geq 10$  dB improvement in at least two audiometric frequencies also had higher mean improvements in SRT ( $18 \pm 12$  dB versus  $3 \pm 9$  dB,  $p = 0.03$ ) and speech-frequency PTA ( $9 \pm 8$  dB versus  $1 \pm 4$  dB,  $p = 0.049$ ) compared with the rest of the cohort, but improvement in WRS remained the same ( $25 \pm 19\%$  versus  $26 \pm 18\%$ ,  $p = 0.89$ ). However, of the 11 patients who presented with initial WRS of  $< 50\%$ , 8 (73%) had posttreatment WRS improved to  $> 50\%$ . The average percent improvement in WRS in these nine patients was  $39 \pm 9\%$ .

Age was not associated with  $\geq 15\%$  improvement in WRS ( $p = 0.82$ ),  $\geq 10$  dB improvement in at least two audiometric frequencies ( $p = 0.88$ ), or  $\geq 10$  dB improvement in SRT ( $p = 0.13$ ). Neither meeting migraine criteria nor receiving earlier treatment was associated with better improvement in any of the audiometric parameters. Patients with aural fullness were more likely to have  $\geq 15\%$  improvement in WRS (9/10, 90%) compared with those without aural fullness (4/9, 44%;  $p = 0.03$ ). Patients who received IT steroid injections in addition to their migraine treatment ( $n = 15$ ) had similar rates of significant improvement in SRT, WRS, and PTA compared with patients who did not receive IT steroid injections (all  $p > 0.05$ ). Independent samples *t* test analysis also demonstrated that the numeric improvement in these parameters was similar between patients who received IT steroids and those who did not receive IT steroid injections (all  $p > 0.05$ ).

The reported medication adverse events, which were not mutually exclusive and usually occurred at higher dosage, included fatigue ( $n = 5$ , 24%), nausea/light-headedness ( $n = 2$ , 10%), dry mouth ( $n = 2$ , 10%), and heart palpitations ( $n = 1$ , 5%), which resulted in de-escalating the dosage and subsequently improved patient tolerance. To our knowledge and the extent of follow-up data, the responders did not experience recurrence of hearing loss after discontinuation of the medications.

## DISCUSSION

This retrospective study of 21 long-term SSNHL patients demonstrated that adjuvant migraine treatment and IT steroid injection led to clinically significant improvement in WRS, SRT, and at least two audiometric frequencies in 68, 40, and 29% of the subjects, respectively. Moreover, 73% of subjects presenting with non-useful hearing ( $< 50\%$  initial WRS) improved to  $> 50\%$  WRS (usable hearing) posttreatment, which can have major implications for the consideration of hearing aid use. Patients who presented with continued aural fullness on the same side as the SSNHL had a higher chance of

**TABLE 1.** Cohort patients' presentations and treatment approaches.

#	Age, Sex	Met Migraine Criteria	Other Symptoms	HL Laterality, Time From SSNHL to Visit	Previous Treatment	Treatment (Dosage at Approx. 6 Wk)	Improvement in WRS ( $\Delta\%$ )
1	74, F	Yes	AF, Tinnitus	R, 11 mo	None	Med: N (10), V (120) IT injections: 3	44
2	60, M	No	None	L, 2 mo	Prednisone + IT	Med: N (60), T (150) IT injections: 4	0
3	62, M	Yes	Tinnitus	L, 4 mo	None	Med: N (50), T (125) IT injections: 2	0
4	56, M	Yes	AF, Tinnitus	R, 6 mo	Prednisone	Med: V (180), T (25) IT injections: 0	48
5	58, F	Yes	MS, AF, Tinnitus	L, 24 mo	None	Med: N (50), T (25) IT injections: 0	32
6	72, F	Yes	MS	L, 3 mo	Prednisone	Med: N (10), T (100) IT injections: 5	28
7	70, M	No	AF	R, 9 mo	Prednisone	Med: N (40), V (120), T (150) IT injections: 3	32
8	73, F	Yes	Tinnitus	L, 15 mo	Prednisone	Med: N (10), T (25) IT injections: 0	4
9	67, M	No	AF	R, 5 mo	Prednisone	Med: N (20), T (150) IT injections: 3	48
10	49, F	Yes	AF, Tinnitus	L, 11 mo	Prednisone + IT	Med: N (30), T (150) IT injections: 3	52
11	79, M	Yes	AF, Tinnitus	L, 4 mo	Prednisone	Med: N (50), V (40) IT injections: 3	23
12	50, M	Yes	Tinnitus	R, 4 mo	None	Med: N (25), V (180), T (180) IT injections: 3	36
13	63, M	Yes	AF, Tinnitus	L, 36 mo	None	Med: N (25), V (180), T (150) IT injections: 2	-
14	36, F	Yes	MS	R, 3 mo	Prednisone + IT	Med: N (25), T (25) IT injections: 1	32
15	81, F	Yes	None	L, 10 mo	None	Med: N (40), V (40) IT injections: 0	28
16	71, F	Yes	AF, Tinnitus	R, 2 mo	None	Med: N (40), V (120), T (150) IT injections: 2	20
17	70, M	Yes	None	R, 5 mo	None	Med: N (50), T (75) IT injections: 0	0
18	51, M	No	Tinnitus	R, 4 mo	None	Med: N (25), T (25) IT injections: 4	11
19	72, F	Yes	AF, Tinnitus	R, 3 mo	None	Med: N (25), T (50) IT injections: 2	-
20	58, M	Yes	AF, Tinnitus	R, 7 mo	Prednisone + Myringotomy	Med: N (75), V (120), T (150) IT injections: 6	40
21	71, M	Yes	AF	L, 18 mo	None	Med: N (25), T (25) IT injections: 0	8

AF indicates aural fullness; F, female; HL, hearing loss; IT, intratympanic steroid; L, left; m, months; M, male; MS, motion sickness; N, nortriptyline; R, right; SSNHL, sudden sensorineural hearing loss; T, topiramate; V, verapamil; WRS, word recognition score.

improvement in WRS. The observed improvement in at least two audiometric frequencies was more predominant among low-frequency thresholds (Fig. 3B), which is similar to our recent report of this treatment regimen in addressing acute (<14 d) SSNHL (18). These findings are significant because the literature on long-term and refractory SSNHL is scarce and these patients are often limited to only steroid therapy recommendations by the clinicians. Our findings suggest a novel treatment for this debilitating condition and may suggest further evidence of an underlying vascular etiology relating SSNHL and migraine.

A recent longitudinal study by Xie et al. (20) reported that 27% of SSNHL patients had persistent hearing loss after 1 month, despite presenting  $\leq 10$  days from symptom onset and receiving steroid therapy. Another study that followed SSNHL patients for 2 to 18 months without treatment showed that of the 113 patients with standard-of-care treatment failure (as measured by PTA), only 13 (12%) had significant improvement in WRS (21). As such, this study's significantly higher percentage of patients with WRS improvement (68%), and the relatively higher WRS percentage increase within the subcohort with



**TABLE 2.** Comparison of pre- and posttreatment audiometry of long-term sudden sensorineural hearing loss patients (n = 21).

Tested Frequency	Pretreatment Hearing Threshold	Posttreatment Hearing Threshold	p Value
250 Hz (dB)	50 ± 20	46 ± 17	0.08
500 Hz (dB)	55 ± 20	49 ± 19	<b>0.01</b>
1000 Hz (dB)	57 ± 21	52 ± 19	<b>0.03</b>
2000 Hz (dB)	60 ± 17	59 ± 16	0.46
4000 Hz (dB)	70 ± 17	68 ± 16	0.34
8000 Hz (dB)	76 ± 13	72 ± 17	0.17
Low-frequency PTA (dB)	57 ± 17	53 ± 15	<b>0.01</b>
Speech-frequency PTA (dB)	60 ± 15	57 ± 13	<b>0.02</b>
High-frequency PTA (dB)	73 ± 14	70 ± 15	0.18
WRS (%)	45 ± 28	70 ± 28	<b>&lt;0.01</b>
SRT (dB)	57 ± 18	50 ± 16	<b>0.01</b>

All values are in mean ± standard deviation. Low-frequency PTA: averages 500, 1000, and 2000. Speech-frequency PTA: averages 500, 1000, 2000, and 4000. High-frequency PTA: averages 4000 and 8000. WRS and SRT were not available for analysis in two and one patients, respectively.

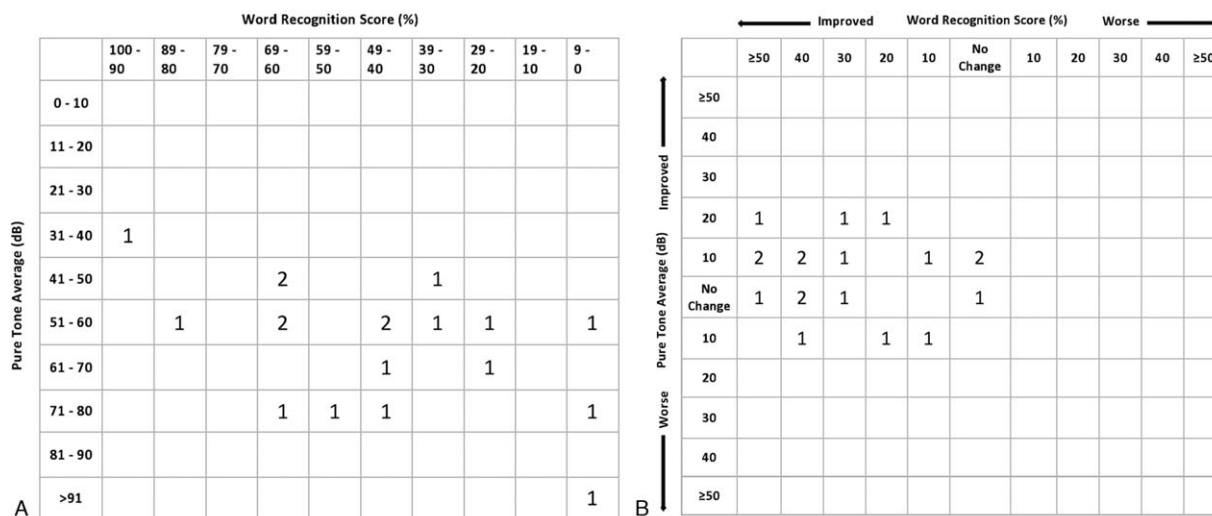
Bold values show statistical significance (p < 0.05).

PTA indicates pure-tone average; SRT, speech recognition threshold; WRS, word recognition score.

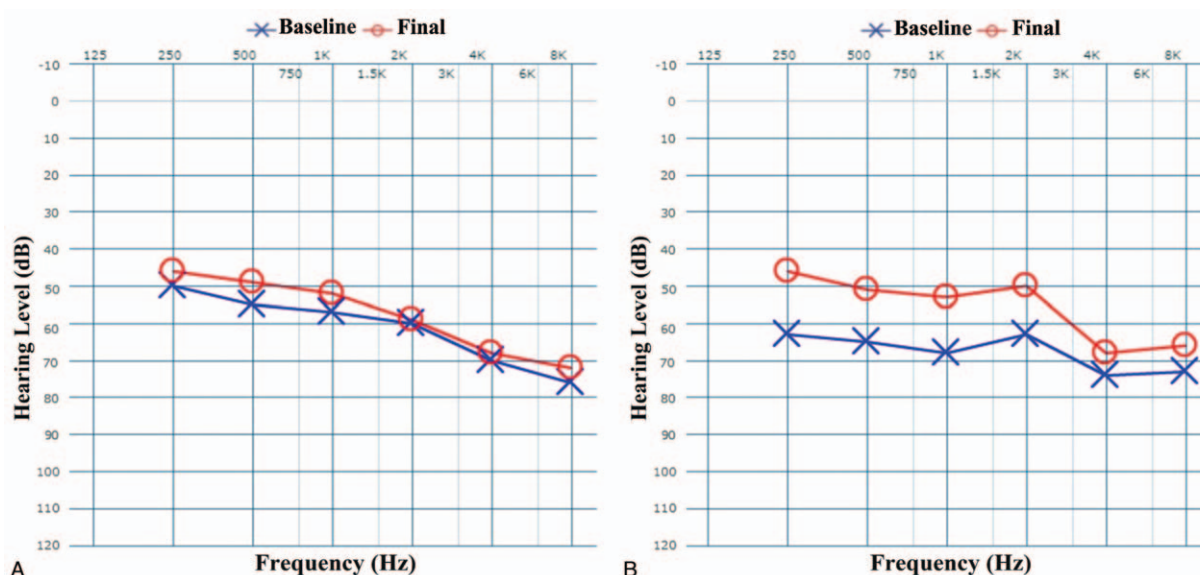
clinically significant WRS improvement (35.6 versus 23.8% (21)) may suggest a novel and efficacious treatment for long-term SSNHL. According to our results, adjuvant migraine medications significantly improved WRS in most patients above adequate thresholds fit for general quality-of-life benefits or consideration for hearing rehabilitation. Although only present in a subcohort of patients, we observed that SRT and PTA could also be improved following this treatment regimen. In our experience, this added efficacy of migraine management is independent of concurrent or previous steroid therapy. This notion is in

line with our recent study reporting superior hearing recovery in short-term SSNHL when supplementing standard-of-care steroid therapy with adjuvant migraine medications (18). This efficacy is likely attributed to underlying migraine-induced cochlear symptoms, including SSNHL. We hypothesize that the possible relationship between migraine and SSNHL is due to the trigeminal innervation of the cochlear vasculature and stria vascularis (22,23). Further supported by our previous reports of the therapeutic benefits of migraine treatments for prolonged aural fullness (24), hyperacusis (25), persistent post-stapedotomy vertigo (26), and Menière’s disease (27), this “otologic migraine” (otologic manifestations of migraine) phenomenon warrants further in-depth research.

Although a history of migraine was largely prevalent in our cohort, we observed that hearing improvement was similar between those who did and did not fulfill migraine criteria. Likewise in a study by Arslan et al. (28), while there was a higher prevalence of migraine among SSNHL patients, hearing recovery was shown to be similar among those with or without migraine. These suggest that the therapeutic benefit of adjuvant migraine management for long-term SSNHL is not just limited to patients with a history of headache, and that migraine and SSNHL may be independently related. This relationship is further shown by recent Korean and Taiwanese nationwide studies in which migraineurs had an increased risk of developing SSNHL (16,17). Specifically, Chu et al. (16) demonstrated that migraine patients (n = 10,280) had a significantly increased incidence rate ratio (1.8, 95% CI 1.22–2.61) of developing SSNHL compared with matched cohorts (n = 41,120). Similarly, in another study of 45,114 migraine patients and 180,456 controls, Kim et al. (17) showed that the adjusted hazard ratio of migraine for SSNHL was 1.34 (95% CI 1.19–1.50). In patients with pre-existing migraine, it is possible that SSNHL is caused



**FIG. 2.** Scattergram of (A) pretreatment and (B) posttreatment hearing results in 19 patients. Pure-tone averages (dB) are labeled on the Y axis and word recognition scores (%) are labeled on the X axis. Each number represents the number of patients with audiometric data that can be categorized in each square. The postoperative scattergram shows 11 of 19 patients with minor PTA improvements of ≤20 dB, and 16 of 19 patients with varied WRS score improvements.



**FIG. 3.** Baseline and final audiograms for (A) all long-term SSNHL patients ( $n=21$ ) and (B) patients who experienced  $\geq 10$  dB improvement in at least two frequencies ( $n=6$ ).

by migraine-induced vasospasm of cochlear vasculature (29) or increased vascular permeability within the cochlea (15). It is hypothesized that cortical spreading depression, which is a wave of slowly propagating neuronal changes resulting in the release of various neuropeptides particularly from the trigeminal nerve, may play an important role in migraine development (30–32). Given that the spiral modiolary artery, cochleovestibular artery, and stria vascularis are innervated by trigeminal nerve fibers (15,23) and trigeminal nerve stimulation results in fluid extravasation within the cochlea (15), we hypothesize that the possible link between SSNHL and migraine is rooted in the trigeminal innervation of the stria vascularis and cochlear vasculature.

Despite our efforts to cautiously collect and interpret data, this study contains several limitations. First, the

**TABLE 3.** Summary of patients with clinically significant improvements in WRS, SRT, PTA, and hearing thresholds among long-term sudden sensorineural hearing loss patients.

Patients with $\geq 15\%$ WRS improvement <sup>a</sup>	13 (68%)
Patients with $\geq 10$ SRT improvement <sup>a</sup>	8 (40%)
Patients with $\geq 10$ PTA improvement	3 (14%)
Patients with $\geq 10$ dB improvement in at least one audiometric frequency	8 (38%)
Patients with $\geq 10$ dB improvement in at least two audiometric frequencies	6 (29%)
Patients with $\geq 10$ dB improvement in at least three audiometric frequencies	3 (14%)
Patients with self-perceived hearing improvement <sup>b</sup>	12 (57%)

<sup>a</sup>WRS and SRT were not available for analysis in two and one patients, respectively.

<sup>b</sup>Self-perceived hearing improvement as reported by patient during posttreatment visit.

PTA indicates pure-tone average; SRT, speech recognition threshold; WRS, word recognition score.

retrospective nature of the study and lack of adequate follow-up for several excluded patients precludes us from concluding the efficacy of this treatment for all long-term SSNHL patients. As such, the results should be interpreted with caution, since they are based on a small and noncontrolled retrospective case series. Future large, randomized controlled studies with appropriate effect size considerations will better determine the true and independent efficacy of migraine medications while controlling for spontaneous recovery, steroid therapy, and other confounders. This future randomized controlled trial can be possibly achieved by enrolling long-term SSNHL patients who do not respond to initial steroid treatment and randomizing them into migraine treatment and placebo groups for comparison. Another limitation of this study was that although migraine management consisted of comprehensive counseling on lifestyle and diet changes, compliance with these parameters was not objectively evaluated. Similarly, this study assumes full compliance with medication regimens and recommended dosage changes, but future prospective studies can further control this by incorporating self-reporting medication adherence measures (33). Furthermore, the regimen of migraine medications was not standardized among patients due to the retrospective nature of the study and personalized treatment of each subject based on side effects and other medications and comorbidities by the senior author. Lastly, while our identification of patients who met migraine criteria was in accordance with the ICHD-3 beta guidelines due to the timeline of data collection, future investigations will need to adopt the newly published and finalized ICHD-3 guidelines (34). Despite these limitations, this study shows a promising and novel treatment for long-term SSNHL patients, many of whom exhaust the limited standard-of-care options without benefits. This study

encourages future investigations to further elucidate the efficacy of migraine medications for patients with refractory and long-term SSNHL.

## CONCLUSION

In this case series of 21 patients, migraine medications and lifestyle changes resulted in significant hearing improvements in a subset of patients with long-term SSNHL presenting at least 6 weeks after symptom onset. Clinically significant improvements in SRT and audiometric frequencies were seen in 40% and 29% of patients, respectively, while WRS was improved in 68% of the cohort, including significant WRS improvements in most patients presenting with initial <50% WRS. For long-term SSNHL patients who are often left without additional treatment options, migraine therapy may be a novel therapeutic approach resulting in improved hearing levels, regardless of whether classic migraine symptoms are present. Future large-scale, controlled investigations are warranted to further explore this treatment for patients with long-term and refractory SSNHL.

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