A Retrospective Comparative Chart Review of Hearing Recovery in Neural and Sensory Type Sudden Sensorineural Hearing Loss Patients

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Abstract

Background

The pathogenesis of Sudden Sensorineural Hearing Loss is complex, and the prognosis for recovery is variable. While the pathological lesion is thought to be localized to the cochlea, recent microRNA findings suggest a primarily neuro-topic pathogenesis at least in some patients. This study seeks to use established hearing-loss categorization systems to distinguish neural from non-neural hearing loss patients and determine if the two groups differ in functional recovery.

Methods

The Charts of 132 Sudden Sensorineural Hearing Loss patients presenting at Vancouver General Hospital (November 2013-June 2019) were retrospectively reviewed. Patients’ characteristics, treatment modality, Pure Tone Audiometric thresholds (averaged across four frequencies: 0.5, 1, 2, and 3 kHz), and Word Recognition Scores were collected. Neural type Sudden Sensorineural Hearing Loss was defined as a presenting Word Recognition Score (<60%), with a Word Recognition Score reduction 20% greater than expected based on the averaged pure tone audiometric loss. Hearing recovery was defined as an improvement of ≥ 10 decibels in pure tone audiometric thresholds.

Results

48 patients meeting the American Academy of Otolaryngology Head and Neck Surgery 2019 diagnostic criteria and with comprehensive data were included. 12 (mean age ± standard deviation: 57.7±14.9 years) and 36 (55.3±15.2 years) patients were classified as neural and sensory Sudden Sensorineural Hearing Loss, respectively. 66.7% (8/12) and (24/36) of neural and non-neural Sudden Sensorineural hearing loss patients, respectively demonstrated hearing recovery. The affected ear’s initial Word Recognition Score (mean ± standard deviation %): 17.1±17.6 and 71.5±35.5 (p < 0.0001), and Word Recognition Score change with treatment: 46.9±29.8 and 3.2±25.8 (p < 0.0001), in neural and non-neural patients, respectively were significantly different.

Conclusion

The hearing recovery rate in neural and sensory type Sudden Sensorineural Hearing Loss patients was similar. Patients with a neural type of hearing loss demonstrated greater word recognition score recovery after treatment than those in the sensory group.

BACKGROUND

Sudden sensorineural hearing loss (SSNHL) is an unexplained acute sensorineural hearing loss of greater than 30 decibels (dB) over a minimum of three pure-tone audiometric averaged (PTA) threshold test frequencies, occurring within 72 hours of onset. Proposed risk factors for SSNHL include advanced age, low folate levels, a diet low in vegetables, and metabolic syndrome. Spontaneous hearing recovery
occurs in 32–65% of SSNHL patients, and is affected by a variety of factors including hearing loss severity, patient age, and concomitant vestibular symptoms. Most cases are idiopathic, with only 10–15% of cases having an identifiable cause. Cochlea ischemia or viral infection are the two predominant proposed pathogenetic mechanisms in idiopathic SSNHL. Studies of plasma and serum microRNAs (miRNAs) in sensorineural hearing loss patients have identified known oxidative stress related miRNAs and others that target oxidative stress related biological pathways. This pathogenic mechanism is supported by the efficacy of hyperbaric oxygen therapy in SSNHL. Interestingly, many of these miRNAs are predominant in the nervous system, suggesting that pathogenetic lesions in SSNHL may be localized to the auditory nerve rather than the cochlea in some patients. Therefore, we adapted an established hearing-loss categorization system to distinguish neural hearing loss patients from non-neural hearing loss patients, and to determine if the two groups differ in functional recovery.

Schucknecht and Gacek described five types of age-related hearing loss that correlate with audiometric patterns of hearing loss: sensory, neural, strial, cochlear conductive, and other. The neural type may present with any kind of PTA slope; however, it is characterized by a speech reception threshold (SRT) elevation that is greater than the PTA elevation by at least 15 dB. On the other hand, Sagers et al. study of primary neuronal degeneration concluded that PTA and word recognition scores (WRS) decreased to the same degree with progressive neuronal loss. We elected to adopt an audiometric characterization of neural type hearing loss more aligned with Schucknecht and Gacek’s description with the aim of only classifying patients with the most severe audiometric features of neuronal degeneration as having a neural pattern of hearing loss. We used this model to investigate differences in hearing recovery, as determined by WRS and PTA, between neural type SSNHL and non-neural SSNHL patients. The 2019 American Academy of Otolaryngology Head and Neck Surgery (AAO-HNS) hearing recovery criteria were used.

METHODS

Study design and participants

This study was approved by the University of British Columbia's Clinical Research Ethics Board (H18-00736). A retrospective chart review of patients who presented with SSNHL to clinics at Vancouver General Hospital (VGH), a tertiary care urban hospital, from November 1 2013 to June 30 2019 was performed. The records of VGH Division of Otolaryngology-Head and Neck Surgery Urgent Access clinics were searched electronically using International Classification of Diseases 9 code 388.2 (Sudden hearing loss, unspecified). Additionally a hand search of hardcopy diagnostic record sheets of patients who attended the VGH Division of Otolaryngology-Head and Neck Surgery Urgent Access clinic, and VGH Audiology department using key terms “SSNHL” or “sudden deafness” or “decrease in hearing” was performed. Prospectively collected data of SSNHL patients who attended the VGH subspecialist Otology and Neurotology clinic and who were willing to participate in SSNHL studies was also studied.
Patients aged 19 years or older with hearing loss > 30 dB over 3 contiguous frequencies within 72 hours of onset were included in the study. Attending staff Otolaryngologists or residents under their supervision made all SSNHL diagnoses. Patients with insufficient presenting or follow-up audiometric data or with hearing loss and identifiable causes such as MRI-confirmed acoustic neuroma, Meniere’s disease, familial hearing loss, autoimmune hearing loss, ototoxic medication, infectious/ inflammatory middle/ inner ear disease were excluded.

Parameters recorded included patient age, sex, history of smoking and alcohol usage, coexisting audiovestibular complaints (e.g., vertigo), medical comorbidities (e.g., diabetes, hypertension, and dyslipidemia), and treatment type (oral steroid, intra-tympanic (IT) steroid, hyperbaric oxygen HBO therapy, and combinations of these treatments). The audiometric data recorded consisted of initial and final follow-up bone and air conduction Pure Tone audiometric thresholds at 0.5 kHz, 1, 2, 3, 4, 6, 8.0 kHz and WRS. A Pure Tone Average (PTA<sub>4</sub>) score was calculated from the mean threshold across four frequencies: 0.5, 1, 2, and (3 or 4) KHz. A case was categorized as a Neural type SSNHL when: 1) the initial WRS was < 60% and 2) the magnitude of the WRS reduction was 20% greater than expected based on the PTA<sub>4</sub>.

**Evaluation of hearing outcomes**

Initial and final post treatment PTA<sub>4</sub> and WRS were used to assess hearing outcome. Patients’ hearing outcome was categorized based on the AAOHNS 2019 Sudden Hearing Loss Clinical Practice Guideline criteria: “completely recovered” (return to within 10 dB of the unaffected ear and recovery of WRS to within 5–10% of the unaffected ear); “partially recovered” (an improvement of ≥ 10 dB in pure tone thresholds but not complete recovery); or “not recovered” (less than 10 dB improvement)<sup>1,6</sup>.

**Statistical Analysis**

Neural and non-neural inter-group mean age, initial and final PTA<sub>4</sub>, initial and final WRS, PTA<sub>4</sub> change, and WRS change were statistically compared by independent samples t-test. The inter-group proportions of patients who: recovered hearing, received combination treatment and the sex distribution of patients were compared with Pearson’s chi square test or Fisher’s exact test. Statistical analyses were conducted with the Statistical Package for the Social Sciences (SPSS) version 25.0 and p value < 0.05 was considered as significant. A Bonferroni corrected p value < 0.0071 was considered significant for multiple t tests. Box and Whisker plots were generated using GraphPad Prism version 9.0.

**RESULTS**

132 cases were identified and reviewed for eligibility. 80 patients were excluded due to incomplete initial and/or final audiogram data. The remaining 52 patients were reviewed for exclusion criteria: three patients were excluded for concomitant use of ototoxic medications, and one patient was excluded due to a history of inflammatory middle ear disease. 48 patients who satisfied the inclusion criteria were studied (Fig. 1), 12 of whom were classified as neural and 36 as non-neural type SSNHL cases. The mean
ages ± standard deviation (SD) of the neural and non-neural type patients 57.7 ± 14.9 and 55.3 ± 15.2 years respectively, were statistically similar. The male: female ratios in neural and non-neural type patients 7:5 and 4:5 respectively, were not statistically different (Table 1). The initial PTA₄ in the affected ears in neural and non-neural type patients 69.6 ± 15.8 decibels (dB) and 54.2 ± 29.4 dB respectively were statistically similar (Table 2). The initial WRS (%) ± SD: 17.1 ± 17.6 and 71.5 ± 35.5 in neural and non-neural type patients were significantly different (p < 0.0001, t-test) (Table 2).

There was no statistically significant inter-group difference in the proportions of patients who received combination oral prednisone and intratympanic (IT) dexamethasone: 16.7% (2/12) and 11.1% (4/36) of the neural and non-neural SSNHL patients respectively. Likewise, there was no statistically significant difference in the 50.0% (6/12) proportion of neural SSNHL patients and 27.8% (10/36) proportion of non-neural SSNHL patients who received combination steroid and HBO therapy (Table 1). Additional patient treatment details medical comorbidities and lifestyle factors are summarised in Table 1.

The hearing recovery rates 66.7% (8/12) and 66.7% (24/36) (p = 1.0, Fisher’s exact test, Table 1), final PTA₄ 44.3 ± 22.5 vs. 44.3 ± 27.9 (p = 0.998, t-test, Table 2) and final WRS scores 60.3 ± 30.6 vs. 68.1 ± 37.7 (p = 0.538, t-test, Table 2) in neural and non-neural types of SSNHL respectively, were similar. However, the affected ear’s WRS change (%) ± SD with treatment: 46.9 ± 29.8 and 3.2 ± 25.8 (p < 0.0001, t-test), in the neural and non-neural SSNHL groups, respectively were significantly different (Table 2 and Fig. 2).
Table 1
Summary of neural and non-neural type SSNHL patient’s demographic, medical history, and treatment details. NA = not statistically analysed.

<table>
<thead>
<tr>
<th></th>
<th>Neural group (n = 12)</th>
<th>Non-neural group (n = 36)</th>
<th>P value (statistical test)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Demographic details</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age in years (mean ± S.D.)</td>
<td>57.67 ± 14.9</td>
<td>55.25 ± 15.2</td>
<td>0.634 (independent samples t-test)</td>
</tr>
<tr>
<td>Sex (male: female)</td>
<td>7: 5</td>
<td>16: 20</td>
<td>0.404 (Pearson Chi-Square)</td>
</tr>
<tr>
<td>% of patients recovered</td>
<td>66.7% (8/12)</td>
<td>66.7% (24/36)</td>
<td>1.0 (Fisher’s exact test)</td>
</tr>
<tr>
<td>(complete and partial)¹,²</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Therapy (% of cases received the treatment)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oral Prednisone only</td>
<td>33.3% (4/12)</td>
<td>50.0% (18/36)</td>
<td>NA</td>
</tr>
<tr>
<td>Combination steroid therapy</td>
<td>16.7% (2/12)</td>
<td>11.1% (4/36)</td>
<td>0.631 (Fisher’s exact test)</td>
</tr>
<tr>
<td>(Prednisone + IT dexamethasone)</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Combination steroid and HBO therapy</td>
<td>50.0% (6/12)</td>
<td>27.8% (10/36)</td>
<td>0.178 (Fisher’s exact test)</td>
</tr>
<tr>
<td><strong>Medical history (number of cases positive)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>History of diabetes</td>
<td>1</td>
<td>2</td>
<td>NA</td>
</tr>
<tr>
<td>History of hypertension</td>
<td>3</td>
<td>9</td>
<td>NA</td>
</tr>
<tr>
<td>History of dyslipidemia</td>
<td>1</td>
<td>3</td>
<td>NA</td>
</tr>
<tr>
<td>History of vertigo</td>
<td>2</td>
<td>9</td>
<td>NA</td>
</tr>
<tr>
<td><strong>Lifestyle factors (number of cases positive)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Smoking</td>
<td>3</td>
<td>2</td>
<td>NA</td>
</tr>
<tr>
<td>Alcohol use</td>
<td>2</td>
<td>5</td>
<td>NA</td>
</tr>
</tbody>
</table>
Table 2
Summary of audiometric data analyses by SSNHL type (neural and non-neural types compared). Significant P values after Bonferroni correction are indicated by *.

<table>
<thead>
<tr>
<th></th>
<th>Initial PTA&lt;sub&gt;4&lt;/sub&gt; of the affected ear (dB)</th>
<th>Final PTA&lt;sub&gt;4&lt;/sub&gt; of the affected ear (dB)</th>
<th>PTA&lt;sub&gt;4&lt;/sub&gt; change of the affected ear after treatment (dB)</th>
<th>Initial WRS of the affected ear (%)</th>
<th>Final WRS of the affected ear (%)</th>
<th>WRS change in the affected ear after treatment (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Neural type</td>
<td>Mean ± S.D.</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>(n = 12)</td>
<td>69.6 ± 15.8</td>
<td>44.3 ± 22.6</td>
<td>25.4 ± 26.4</td>
<td>17.1 ± 17.6</td>
<td>60.3 ± 30.6</td>
<td>46.9 ± 29.8</td>
</tr>
<tr>
<td>Non-neural type</td>
<td>Mean ± S.D.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(n = 36)</td>
<td>54.2 ± 29.4</td>
<td>44.3 ± 27.9</td>
<td>10.9 ± 20.4</td>
<td>71.5 ± 35.5</td>
<td>68.1 ± 37.7</td>
<td>3.2 ± 25.8</td>
</tr>
</tbody>
</table>

**DISCUSSION**

The proportion of patients experiencing hearing recovery did not vary significantly between the neural and non-neural SSNHL groups. No significant difference was seen in the initial PTA<sub>4</sub>, PTA<sub>4</sub> gain, initial WRS and final PTA<sub>4</sub> between the neural and non-neural SSNHL patients. However, neural SSNHL patients had significantly poorer initial WRS and demonstrated greater WRS gain in the affected ear with treatment compared to non-neural SSNHL patients.

The cochlea is generally thought to be the site of the pathological changes resulting in hearing loss in SSNHL patients though different mechanisms are proposed.<sup>10</sup> This contrasts with sudden onset vertigo, where different sites of pathology are accepted as possible causes for the vertigo. Specifically, the vestibular nerve is accepted as a possible site of disease as reflected by the diagnosis of vestibular neuritis, while the labyrinth is the presumed site when vertigo is accompanied by sensorineural hearing loss as in Meniere’s disease. In SSNHL there are no widely accepted guidelines for distinguishing neural (auditory nerve) SSNHL from sensory (cochlea specific) SSNHL. We used Schucknecht and Gacek’s<sup>14</sup> criteria for defining neural and non-neural types of SSNHL and observed a difference in mean WRS at presentation consistent with the application of our diagnostic criteria.

Surprisingly, the neural SSNHL patients demonstrated greater improvement in WRS with treatment than the non-neural patients. The groups did not vary by age, sex, or severity of PTA<sub>4</sub> on presentation. There were too few cases with vertigo to allow robust inter-group statistical comparison, 2 of 12 (16.7%) and 9 of 36 (25%) of patients in the neural and non-neural groups respectively. Analysis by treatment received
likewise did not suggest a significant difference in the neural and non-neural SSNHL patients. Importantly, the proportion of neural SSNHL (50%) who received triple therapy was not significantly different to the proportion of non-neural patients (27.8%) undergoing the same (Table 1). Therefore, it is not expected that an inter-group difference in the treatment effect of HBO will be discerned in this study though the benefit of HBO on PTA threshold improvement is documented. 

This study found a difference in WRS recovery based on the pathological site of lesion in SSNHL patients which has not been described before. Chang et al, support the importance of classifying audiological patterns of presenting hearing loss in SSNHL as these appear to determine prognosis. Their classification system was however based only on the PTA and did not include speech discrimination findings. The current study emphasizes the need to classify initial patterns of hearing loss comprehensively using both PTA and WRS.

In common with other retrospective studies, missing and incomplete data documentation is a limitation. 48 patients were included in the study after reviewing 132 case records for eligibility. 80 cases were excluded due to missing data, which reduced the number of patients available for analysis, an issue that is best rectified with a prospective study design. The small sample sizes of the neural and non-neural subgroups precluded robust comparison of sub-group patient characteristics (e.g., vertigo) known to influence hearing prognosis.

CONCLUSION

This study utilized audiometric findings at presentation in SSNHL patients to classify hearing losses as neural or non-neural. Our hypothesis that patients with a neural pattern of hearing loss are as likely to recover as those with a non-neural pattern was supported. However, SSNHL patients with a neural type hearing loss demonstrate greater WRS gain in response to treatment than those with a sensory type of loss. Future studies should prospectively investigate the differences in hearing outcomes in the neural type of SSNHL, including how the presence of features such as severity of hearing loss, age at presentation, comorbidities, dose and timing of treatment, and associated vertigo affect prognosis.

Abbreviations

SSNHL
Sudden sensorineural hearing loss
PTA
Pure tone audiometry
WRS
Word recognition score
AAO-HNS
American Academy of Otolaryngology–Head and Neck Surgery
HBO
Declarations

Ethics approval and consent to participate: Ethics approval was obtained from the UBC CREB.

Consent for publication: Not applicable.

Availability of data and materials: The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Competing interests: The authors declare that they have no competing interests.

Funding: None.

Contribution of Authors:

- **Conception and design:** RX, TJ, DN, PW
- **Acquisition of data:** TJ, RX, PW, AA, ML, RG, DN
- **Statistical analysis and interpretation of data:** PW, RG, DN
- **Drafting of manuscript:** RX, PW, TJ, AA, ML, -
- **Critical revision of manuscript for important intellectual content:** DN, PW, RX, TJ, RG
- **Final revision and manuscript approval:** RG, RX, PW, TJ, AA, ML, DN
- **Supervision:** DN

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References


Figures
Flow diagram of patient charts that were included and excluded in our analysis. 48 of 132 patients were included after being reviewed for eligibility. 80 patients were excluded for missing audiogram data, and upon review of exclusion criteria, 3 further patients were excluded for ototoxic medications and 1 for inflammatory middle ear disease. 12 patients were classified into the neural SSNHL category, and 36 patients were classified into the non-neural SSNHL category.

**Figure 1**

Flow diagram of patient charts that were included and excluded in our analysis. 48 of 132 patients were included after being reviewed for eligibility. 80 patients were excluded for missing audiogram data, and upon review of exclusion criteria, 3 further patients were excluded for ototoxic medications and 1 for inflammatory middle ear disease. 12 patients were classified into the neural SSNHL category, and 36 patients were classified into the non-neural SSNHL category.
Box and Whisker plots illustrate the neural and non-neural type SSNHL patients' audiometric data before and after treatment. The lower quartile (Q1) or 25th percentile of the dataset forms the lower margin of the box; the median (Q2) or 50th percentile of the dataset is illustrated as a line within the box; the upper quartile (Q3) or 75th percentile of the dataset is represented by the upper margin of the box. The inter-quartile range is the distance from Q1 to Q3. Minimum and maximum dataset values were used to create
the Whiskers, and the individual patient scores shown as points are superimposed in each plot. Actual P values are illustrated in each panel and a Bonferroni corrected P value < 0.0071 was considered significant.