Hearing Outcome of Low-tone Compared to High-tone Sudden Sensorineural Hearing Loss

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Abstract

Introduction Low-tone sudden sensorineural hearing loss (SSHL) is a well-recognized disease, in which the hearing loss is restricted to low frequencies. In contrast to low-tone SSHL, high-tone SSHL is characterized by high-frequency (4,000, 8,000 Hz) hearing loss and preservation of low-, middle-frequency hearing.

Objective The objective of this study is to compare the hearing recovery and long-term outcome of low-tone SSHL with those of patients affected by high-tone SSHL in a follow-up of ~ 3 years.

Methods The low-tone SSHL and high-tone SSHL groups included 27 and 20 patients, respectively; the patients of both groups were treated with intravenous steroids. Predictive factors (gender, affected side, delay of treatment, follow-up time) were also examined.

Results Overall, complete hearing recovery was observed in 77.7% of the patients in the low-tone SSHL group and in 15% of the patients in the high-tone SSHL group. In the high-tone SSHL group, a higher proportion of patients reported tinnitus compared with the low-tone SSHL group (13 cases [65%] versus 3 cases [11%]); however, recurrences were more common in the low-tone SSHL (22%, 6 patients) compared with the high-tone SSHL (2 cases [10%]) group. No predictive factor was found to statistically impact on hearing outcome.

Conclusion After initial therapy, the low-tone SSHL patients have more favorable hearing outcome than high-tone SSHL patients. However, recurrences occurred more frequently in the low-tone SSHL group, while the high-tone SSHL group was more often accompanied by residual symptoms, such as tinnitus.

Introduction

Low-tone sudden sensorineural hearing loss (SSHL) is an already known clinical entity, presenting with low-frequency hearing loss and preservation of high-tone hearing, without vertigo.¹ Abe² described SSHL as an independent disease after studying 39 patients in 1982. Since then, low-tone SSHL was often discussed in Japan and Korea, but less documented in the European or North American studies. The incidence of low-tone SSHL is estimated to be ~ 40 to 60/100,000 based on Japanese regional surveys.³

On the other hand, high-tone SSHL has not been extensively studied so far, which is characterized by elevation of the thresholds in the high-frequency range and preservation of low-, middle-frequency hearing. In this study, we retrospectively reviewed the records of patients with the diagnosis of low-tone SSHL and compared their hearing thresholds outcome, hearing recovery and long-term symptoms with those of patients affected by high-tone SSHL. Predictive factors affecting the hearing outcome in a follow-up of ~ 3 years after treatment were also examined.
Methods

The study sample consisted of 47 patients divided into 2 groups, the low-tone SSHL group (27 patients, 10 males, 17 females), and the high-tone SSHL group (20 patients, 8 males, 12 females). The patient characteristics of the two groups are summarized in Table 1. Retrocochlear disease, otologic surgery, acoustic trauma (or barotrauma), acute or chronic otitis media and Ménière disease were excluded from this study.

Low-tone type SSHL was defined as the hearing loss for which the average from 3 low frequencies (125, 250, and 500 Hz) was ≥ 30 dB, and the average from 3 high frequencies (2,000, 4,000 and 8,000 Hz) was ≤ 20 dB. High-tone SSHL was always associated with a sensation of loss of auditory acuity, tinnitus or ear fullness and was characterized by at least a 15-dB difference in hearing level at high frequencies (4,000 and/or 8,000 Hz) in comparison with that of the healthy side; moreover, hearing thresholds at other frequencies were within the normal limits on the affected side.

All the patients were treated in our clinic with intravenous steroids (dexamethasone, 8mg, 3 times daily and tapered every 3 days over 10 days). After discharge, the patients of the low-tone SSHL group were followed for a mean of 3.3 years (standard deviation [SD]: 2.9 years), and those of the high-tone SSHL group for a mean of 2.8 years (SD:1.6 years).

The age, gender, affected side, delay of treatment and follow-up period were also statistically studied in relation to the hearing recovery in the two groups. To better study the effect of the time gap between the onset of sudden hearing loss and treatment, each group was divided into 2 subgroups, the early and the late; the early subgroup started the treatment within 2 days of SSHL onset, and the late subgroup, in which the treatment was delayed for more than 2 days of SSHL onset.

At the last follow-up, the final outcome in each group was recorded as follows: complete recovery: final hearing level within 0 to 20 dB, or the average gain was 10 dB or less between 2 ears. Partial recovery: the average gain was improved 10 dB or more when compared with the initial audiogram. Unchanged: the final average gain was within 10 dB. Moreover, each band of frequencies was statistically compared before and after the treatment, for the low-tone SSHL group (125, 250, 500 Hz) and for the high-tone SSHL group (4,000 and 8,000 Hz, respectively). The patients were also asked to report on persistent tinnitus, possible recurrences of sudden hearing loss or episodes compatible with Ménière disease.

Statistics

The variables in this study included gender, age, affected side, follow-up period, hearing thresholds at each frequency pre and posttreatment, time gap between the onset of sudden hearing loss and the start of treatment.

Absolute and relative frequencies for all demographic and clinical variables were obtained. All variables were checked for normality via the Kolmogorov-Smirnov test. Non-parametric tests were used where applicable. Collinearity among scores and other variables in the study was assessed via a correlation matrix, using Pearson r or Spearman ρ correlation coefficient. The Student t-test or the Mann-Whitney U-test was used for independent sample comparisons. Paired t-test or paired Wilcoxon signed rank test was used for paired comparisons. Pearson Chi square was used for categorical comparisons. The Type I error probability associated with all tests in this study was set to 0.05. The statistical analyses were performed using the IBM SPSS Statistics for Windows, version 23.0 package (IBM Corp., Armonk, NY, USA).

Results

The pattern of hearing levels (based on pure tone average at each frequency) of pre and posttreatment is illustrated in Fig. 1 and 2 for the low-tone and high-tone SSHL groups, respectively. A very statistically significant improvement in hearing was found for all low frequencies (125, 250, 500 Hz) in the low-tone SSHL group (Table 2). In the high-tone SSHL group, a significant hearing recovery was revealed at 4,000 Hz; however, there was no improvement in hearing at 8,000 Hz (Table 3).

According to Table 4, at the final follow-up, the low-tone SSHL group showed better hearing outcome compared with the high-tone SSHL group. Complete hearing recovery was observed in 77.7% of patients of the low-tone SSHL group compared with 15% of cases of the high-tone SSHL group.

In our study, gender, age, affected side and follow-up period had no statistically significant impact on hearing outcome (Table 1); the earlier onset of treatment would possibly affect the hearing recovery in the low-tone group (statistical

Table 1 Patient characteristics with low- and high-tone sudden sensorineural hearing loss

<table>
<thead>
<tr>
<th>Group</th>
<th>Gender (males/females)</th>
<th>Age (range in years, mean ± SD)</th>
<th>Side (right/left)</th>
<th>Delay of treatment (range in days, mean ± SD)</th>
<th>Follow-up (in years, mean ± SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low-tone (n = 27)</td>
<td>10/17</td>
<td>19–72, 44.1 ± 13.1</td>
<td>13/14</td>
<td>0–14; 2.7 ± 3.3</td>
<td>3.3 ± 2.9</td>
</tr>
<tr>
<td>High-tone (n = 20)</td>
<td>8/12</td>
<td>16–64, 41.4 ± 13.5</td>
<td>11/9</td>
<td>0–60; 8.6 ± 14.2</td>
<td>2.8 ± 1.6</td>
</tr>
<tr>
<td>Post-treatment</td>
<td>p = 0.537</td>
<td>p = 0.496</td>
<td>p = 0.433</td>
<td>p = 0.089</td>
<td>p = 0.947</td>
</tr>
</tbody>
</table>

Abbreviation: SD, standard deviation.
Fig. 1 Audiometric configuration of low-tone sudden sensorineural hearing loss based on average hearing thresholds, pre- and posttreatment, at each frequency (SD: standard deviation).

Fig. 2 Audiometric configuration of high-tone sudden sensorineural hearing loss based on average hearing thresholds, pre- and posttreatment, at each frequency (SD: standard deviation).

Table 2 Low-tone sudden sensorineural hearing loss group; pure tone audiogram average threshold by frequency (dB HL) pre and posttreatment

<table>
<thead>
<tr>
<th>Hz</th>
<th>Pre</th>
<th>Post</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>125</td>
<td>49.44 ± 6.699</td>
<td>20.56 ± 10.860</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>250</td>
<td>48.15 ± 6.954</td>
<td>19.26 ± 10.442</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>500</td>
<td>41.48 ± 10.725</td>
<td>15.93 ± 8.775</td>
<td>&lt; 0.001</td>
</tr>
</tbody>
</table>

Table 3 High-tone sudden sensorineural hearing loss group; pure tone audiogram average threshold by frequency (dB HL) pre and posttreatment

<table>
<thead>
<tr>
<th>Hz</th>
<th>Pre</th>
<th>Post</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>4,000</td>
<td>40.00 ± 24.815</td>
<td>28.25 ± 20.981</td>
<td>0.016</td>
</tr>
<tr>
<td>8,000</td>
<td>64.00 ± 17.137</td>
<td>54.75 ± 21.611</td>
<td>0.081</td>
</tr>
</tbody>
</table>
study, high-tone SSHL was audiometrically de
decade of life
female preponderance and peak incidence during the fourth
tinnitus, autophony or fullness in the affected ear; moreover,
characterized by a sensation of loss of auditory acuity,
tone SSHL were quite similar to those in low-tone SSHL,
frequency band (77.7% versus 15%). The symptoms in high-
 poorer recovery rates than those with hearing loss in low-
with hearing loss in the high-frequency band clearly had
contrast to low-tone SSHL. According to the results, patients
thresholds elevation restricted to high-frequencies, in con-
tion related to the time elapsed (less/more than 2 days) from the
onset of hearing loss to the start of treatment.

At the last follow-up (~ 3 years) in the low-tone SSHL
group, 3 (11%) patients were still complaining of tinnitus, and
another 6 (22%) patients had recurrences of low-tone
SSHL in the diseased ear, half of them in the first year of the
first attack; Ménière disease occurred in the diseased ear of
another 2 (7%) patients at 1.5 and 10 years after SSHL onset,
respectively. Overall, no complete relief from symptoms was
reported in 40% (11 patients) of cases in the low-tone SSHL
group.

Compared with the low-tone SSHL group, a higher propor-
tion (15/20 cases, 75%) of patients in the high-tone SSHL

group reported persistent symptoms. From these, 13 (65%)
patients still had tinnitus in the diseased ear and another 2
patients suffered from 2 (10%) recurrences; 1 patient experi-
enced a 2nd episode of SSHL in the diseased ear 1 month
later, and the other patient 3 years later. In this group, no
patient experienced episodes compatible with Ménière
disease.

**Discussion**

Most authors have already reported that the prognosis of
low-tone SSHL (or upward-sloping audiogram) is better than
that of high-tone SSHL (or downward-sloping audiogram),\textsuperscript{1,5}
although this is not in agreement with other studies.\textsuperscript{6,7} In our
study, high-tone SSHL was audiometrically defined as
thresholds elevation restricted to high-frequencies, in con-
trast to low-tone SSHL. According to the results, patients
with hearing loss in the high-frequency band clearly had
poorer recovery rates than those with hearing loss in low-
frequency band (77.7% versus 15%). The symptoms in high-
tone SSHL were quite similar to those in low-tone SSHL,
characterized by a sensation of loss of auditory acuity,
tinnitus, autophony or fullness in the affected ear; moreover,
female preponderance and peak incidence during the fourth
decade of life\textsuperscript{8} seem to be common in these two clinical
entities (~Table 1).

Our treatment for low-tone SSHL group was based on
intravenous steroid with complete recovery of hearing in
77.7% of patients, which is comparable to the findings of other
relatively recent studies.\textsuperscript{1,9} Jung et al\textsuperscript{1} found an audiometric
improvement rate of 76% with oral steroids alone (follow-up:
8 weeks), which was better than 50% achieved after intratym-
panic steroid injections alone and 76.9% with combination of
the two methods. In a study with almost 2 years of follow-up,
Roh et al\textsuperscript{10} demonstrated complete hearing improvement in 75%
of patients after treatment mainly with oral steroids, which was
very close to the results obtained in our last follow-up. How-
ever, Morita et al\textsuperscript{11} showed lower recovery rates with oral
steroid alone (63%) but with 2 months follow-up. It has also
been advocated that when diuretics were added to steroids the
recovery rates are significantly improved (78.2% to 83.9%).\textsuperscript{1,10,11}

In high-tone SSHL, the hearing recovery was statistically
significant after treatment at all frequencies, except at
8,000 Hz (~Table 3). We have no explanation why the
treatment for high-tone SSHL is ineffective at 8,000 Hz. It is
possible that this region of cochlea at the end portion of the
basal turn is most vulnerable to damage, reflecting the
gradual downward-sloping hearing loss in presbycusis or
otoxicity with degradation of hearing thresholds at higher
frequencies. It has been reported that the levels of gluta-
thione, an antioxidant, tend to be lower at the most basal
cochlear turn hair cells and inversely increasing toward the
apex;\textsuperscript{12} glutathione peroxidase is an enzyme that alter
reactive oxygen species to less damaging forms.\textsuperscript{12}

The pathophysiological mechanism of low-tone SSHL is still
unclear. According to studies, the low-tone SSHL may be a
variant of Ménière disease, or the beginning period of
Ménière disease.\textsuperscript{1,13} Yamasoba et al,\textsuperscript{14} using glycerol test
and electrocochleogram (elevated SP/AP ratio), suggested
that low-tone SSHL might be caused by endolymphatic hydrops. Fuse et al\textsuperscript{15}
reported that the etiology of low-
tone SSHL involves an autoimmune response of the endo-
lymphatic sac that induces endolymphatic hydrops. On the
other side, Choi et al\textsuperscript{16} supported that low-tone SSHL might
be a different disease entity from Ménière disease, since only
1 among 18 patients who had been checked with electroco-
chleogram during acute low-tone SSHL showed elevated SP/
AP ratio. Moreover, Wu and Young\textsuperscript{17} demonstrated that low-
tone SSHL should be differentiated from Ménière disease on
the basis of vestibular evoked myogenic potentials (VEMPs),
since most patients with low-tone SSHL revealed normal
VEMPs; in contrast, 50% of Ménière disease patients with
low-tone hearing loss showed abnormal VEMPs. In our study,
low-tone SSHL progressed to Ménière disease in only 2 (2/27,
7%) patients at 1.5 and 10 years after the SSHL onset.
Similarly, Yamasoba et al\textsuperscript{18} reported that 5 (11%) out of 45
patients followed up for more than 3 years developed
Ménière disease. Compared with low-tone SSHL cases, our
patients with high-tone SSHL did not develop Ménière dis-
ease, although initially there were a few complaints of lightheadedness and instability. It seems that low-tone
SSHL is not the same disease as Ménière disease because a
limited proportion of low-tone SSHL cases progressed to
Ménière disease.

However, recurrences occurred more frequently in the
low-tone SSHL (22%) than in the high-tone SSHL group (10%).
It has been postulated\textsuperscript{17} that patients with low-tone SSHL

<table>
<thead>
<tr>
<th>Table 4 Hearing recovery at the last follow-up in low- and high-tone sudden sensorineural hearing loss</th>
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</thead>
<tbody>
<tr>
<td>Complete</td>
</tr>
<tr>
<td>Low-tone</td>
</tr>
<tr>
<td>(~ n = 27)</td>
</tr>
<tr>
<td>21 (77.7%)</td>
</tr>
<tr>
<td>High-tone</td>
</tr>
<tr>
<td>(~ n = 20)</td>
</tr>
<tr>
<td>3 (15%)</td>
</tr>
</tbody>
</table>

Note: The low-tone sudden sensorineural hearing loss group showed better hearing outcome compared with the high-tone sudden sensorineural hearing loss group (Pearson Chi-squared test, p < 0.001)
suffering of recurrent episodes of hearing loss tended to have endolymphatic hydrops (higher summation potential/action potential [SP/AP] ratio of electrocochleography), whereas those without recurrent episodes do not. According to previous reports, the incidence of recurrences after low-tone SSHL onset has ranged from 9 to 45%, the majority of them were documented within one year of the first attack.

Indeed, Oishi et al supported that if the low-tone SSHL patients display hearing fluctuations within one year after the initial attack, about half of them exhibited high- and pan-frequency hearing loss within 10 years of onset; nevertheless, with regard to progression of hearing loss at high frequencies we should consider the effect of aging.

In both groups, no factors such as gender, age, affected side, follow-up period, hearing thresholds at each frequency pre and posttreatment have been found to be significant in prognosis. The earlier onset of treatment would possibly affect the hearing recovery in the low-tone SSHL group (statistical trend). In addition, a prompt treatment with steroids within 2 days from the onset of low- or high-tone SSHL was not apparently related to the affect the hearing recovery in the low-tone SSHL group.


Wong AC, Ryan AF. Mechanisms of sensorineural cell damage, death and survival in the cochlea. Front Aging Neurosci 2015;7:58


Conclusion

High-tone SSHL, which is characterized by hearing loss at high frequencies, shows poor recovery rates and residual symptoms, such as tinnitus; low-tone SSHL has a more favorable hearing outcome but is more often associated with recurrences and less commonly progressed to Ménière disease. Further studies are needed, as well as more extensive research, to better understand the etiology of both low- and high-tone SSHL.

References


