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Clinical Study of 35 Patients with Acute Acoustic Hearing Disorder

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Abstract

We conducted a clinical study on 35 patients (42 ears) with acute acoustic hearing disorder who visited the otolaryngology department of Himeji St. Mary's Hospital during 12 years, from January 2012 to December 2023. The patients' ages ranged from 16 to 81 years, with an average of 34.7 years (median age: 27 years); there were 27 male and 8 female patients. The disease was caused by exposure to shooting sounds in 22 patients (shooting sound group) and exposure to other strong and loud sounds in the remaining 13 patients (other high-intensity sound group). The mean age was significantly lower, and the interval from the onset of symptoms to consultation was shorter in the shooting sound group than in the other high-intensity sound group. Regarding hearing type, the C^5-dip type was the most common (11 ears), followed in frequency by the gradually down-sloping, sharply down-sloping, and flat type. The overall hearing improvement was as follows: cured: 40.5%; markedly recovered: 11.9%; recovered: 19.0%; and unchanged: 28.6%. The degree of hearing improvement classified by hearing type was good for all of the C^5-dip, dip (2K), and V-shaped types. Patients younger than 30 years, with a short interval from the onset to first visit, and with bilateral hearing loss showed satisfactory hearing improvement. There was a tendency for the degree of hearing improvement to be better in the shooting sound group than in the other high-intensity sound group.

Keywords
- clinical study
- acute acoustic hearing disorder
- shooting sound
- other high-intensity sound
- C^5-dip

Introduction

Acute acoustic hearing disorder is characterized by sudden inner ear dysfunction due to exposure to high-intensity sounds in various settings such as explosions and concerts. The standard treatment strategy of pharmacotherapy is similar to that for sudden deafness; however, preventive measures for predictable exposure to high-intensity sounds are also important. There have been few clinical studies on acute acoustic hearing disorder in a large number of patients[1–4]; however, no previous study has compared cases of acute acoustic hearing disorder caused by exposure to shooting sounds with those caused by exposure to other high-intensity sounds.

Here, we report a clinical study of acute acoustic hearing disorder cases in our department, including comparisons between those caused by exposure to shooting sounds (the shooting sound group) and those caused by exposure to other strong and loud sounds (the other high-intensity sound group).

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Materials and Methods

Patients and Data Collected for Comparison

In this study, we included a total of 35 patients (42 ears) with acute acoustic hearing disorder who visited the outpatient clinic of the Department of Otorhinolaryngology of Himeji St. Mary's Hospital during 12 years from January 2012 to the end of December 2023 and were followed up for at least 2 weeks (including patients whose hearing disorder was resolved within 2 weeks). All patients were treated with 20 to 100 mg prednisolone or 100 to 500 mg water-soluble hydrocortisone as the principal drug along with mecobalamin and adenosine triphosphate preparations at the discretion of the attending otorhinolaryngologists. Additionally, low-molecular-weight dextran and prostaglandin E1 preparations were used to treat 15 and 10 patients, respectively (each of these patients received both simultaneously or only one of the two drugs).

Statistical Analysis

The data collected for comparisons were: (1) age and sex, (2) affected ears, (3) cause, (4) age by cause (shooting vs. other high-intensity sound groups), (5) number of days between onset and first visit, (6) affected ear by cause (shooting vs. other high-intensity sound groups), (7) audiometric patterns, (8) audiometric patterns by cause (shooting vs. other high-intensity sound groups), (9) overall hearing improvement levels, (10) hearing improvement level by audiometric patterns, (11) hearing improvement level by age, (12) hearing improvement level by the number of days between onset and first visit, (13) hearing improvement level by laterality (unilateral vs. bilateral), and (14) hearing improvement level by cause (shooting vs. other high-intensity sound groups).

The Mann–Whitney *U*-test was used to compare groups. Mini StatMate software was used for statistical analysis, and $p < 0.05$ was considered statistically significant.

This study was approved by the clinical research ethics committee of our hospital (approval number: S023-016).

Results

Age and Sex

The age of patients ranged from 16 to 81 years, with the highest number of patients in their 20s. The mean and median ages were 34.7 and 27 years, respectively. There were 27 male and 8 female patients, and approximately 80% of the patients were men (►**Fig. 1**).

Affected Ears

The left ear, the right ear, and both ears were affected in 13 cases (37.1%), 15 cases (42.9%), and 7 cases (20.0%), respectively.

Cause

The most common cause was exposure to shooting sounds, as observed in 22 cases (27 ears). Acute hearing disorder was caused by exposure to nonshooting high-intensity sounds in 13 cases (15 ears), including 5 cases caused by exposure to hitting (crushing) sounds (including 4 cases involving hammers, and 1 case involving hands), 2 cases caused by exposure to speaker sounds, and 1 of each case caused by

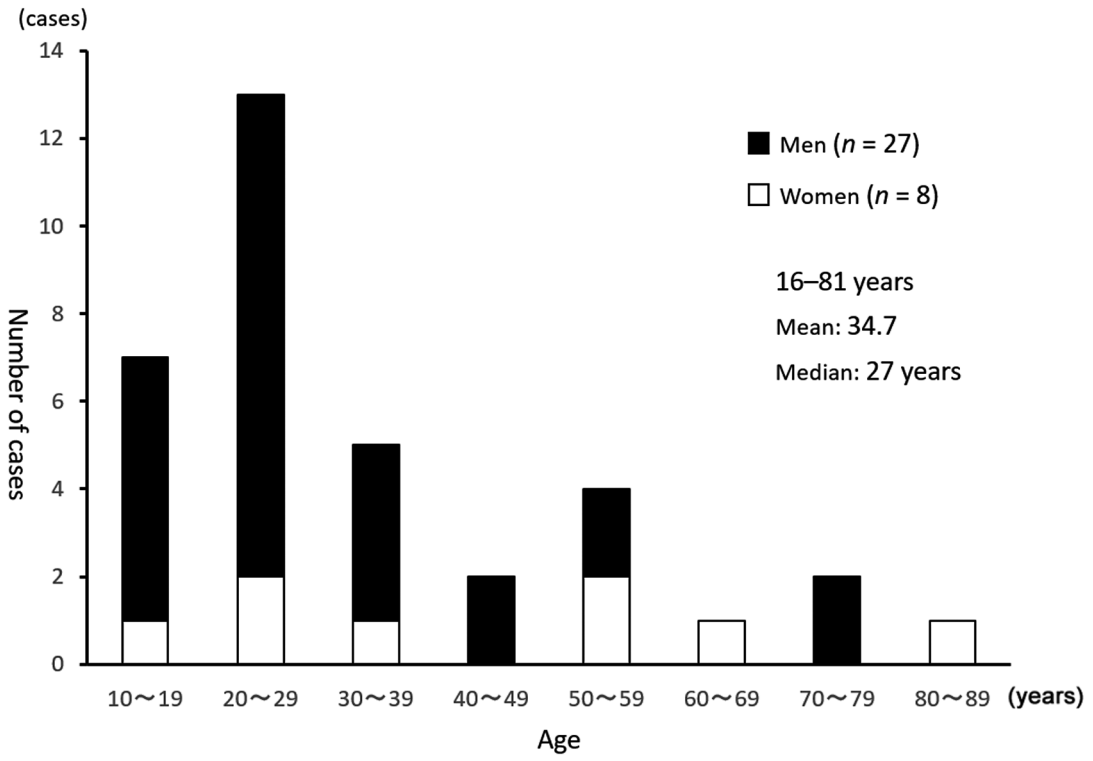

Fig. 1 Age and sex. The highest number of patients were in their 20s and approximately 80% of the patients were men.

exposure to explosion sound from burning bamboo, whistle sound, loud voice, pachinko game sound, engine sound, and game sound.

Age by Cause: Shooting versus Other High-Intensity Sound Groups

The mean age of patients in the shooting sound group was 26.6 years, whereas that of patients in the other high-intensity sound group was 48.5 years. Thus, patients in the shooting sound group were significantly ($p < 0.005$) younger than patients in the other high-intensity sound group (►**Fig. 2**).

Number of Days between Onset and First Visit

The number of days between onset and first visit ranged from 0 (the same day) to 28 days, with a mean and a median of 4.2 and 2 days, respectively. The mean and median days between the onset and the first visit in the shooting sound group were 2.7 days and 1 day, whereas those in the other high-intensity sound group were 6.8 and 4 days, respectively. Thus, patients in the shooting sound group had a significantly ($p < 0.001$) smaller number of days between onset and first visit than patients in the other high-intensity sound group (►**Fig. 3**).

Affected Ear by Cause: Shooting versus Other High-Intensity Sound Groups

In the shooting sound group, the left ear was affected in 10 cases, the right ear was affected in 7 cases, and both ears were affected in 5 cases (auditory acuity decline: the left ear more than the right ear in 3 cases and the right ear more than the left ear in 2 cases). Among the four patients whose dominant hand could be confirmed, the left ear was affected in three right-handed patients—both earplugs were removed in one case, the left earplug was removed in one case, and neither of the earplugs was removed in one case—and the right ear was affected in one right-handed patient—the right earplug was removed. At least seven patients in the shooting sound group did not wear an earplug in the affected ear, which were the left and right ears in five and two cases, respectively. In the other high-intensity sound group, the left ear, the right ear, and both ears were affected in three, eight, and two cases, respectively. These results indicate that the ear without an earplug and the left ear tended to be affected more frequently in the shooting sound group.

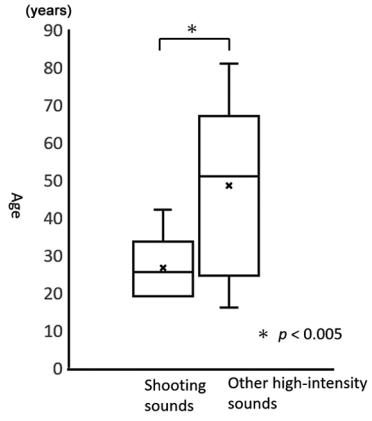

Fig. 2 Age by cause: shooting versus other high-intensity sound groups. Patients in the shooting sound group were significantly ($p < 0.005$) younger than patients in the other high-intensity sound group.

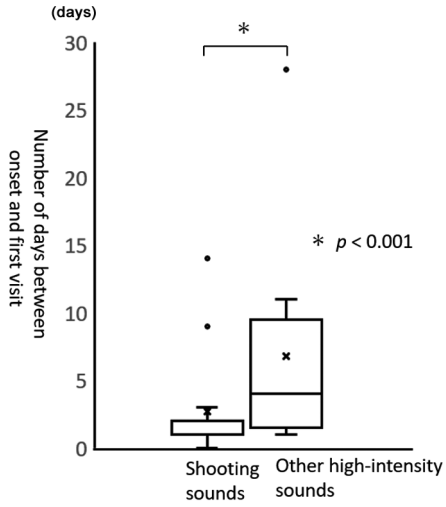

Fig. 3 Number of days between onset and first visit. Patients in the shooting sound group had a significantly ($p < 0.001$) smaller number of days between onset and first visit than patients in the other high-intensity sound group.

Audiometric Patterns

Audiometric patterns of the patients were classified into the following types: gradually down-sloping (decreases at 2K, 4K, and 8K Hz), sharply down-sloping (decreases at 4K and 8K Hz), C^5-dip (a decrease at 4K Hz), dip (2K) (a decrease at 2K Hz), dip (2K, 4K) (decreases at 2K and 4K Hz), flat, V-shaped, convex, and up-sloping types.

The most common type was C^5-dip (11 ears), followed by gradually down-sloping (8 ears), sharply down-sloping and flat (5 ears each), dip (2K) (4 ears), V-shaped (3 ears), dip (2K, 4K) (2 ears), convex (2 ears), and up-sloping (2 ears; ►**Fig. 4**). The audiometric patterns in the seven patients without earplugs were gradually down-sloping and V-shaped types for two ears each and C^5-dip, dip (2K), and dip (2K, 4K) for one ear each.

Audiometric Patterns by Cause: Shooting versus Other High-Intensity Sound Groups

Among the 27 ears in the shooting sound group, the audiometric patterns were C^5-dip in 6 ears, gradually down-sloping in 5 ears, sharply down-sloping and dip (2K) in 4 ears each, V-shaped in 3 ears, dip (2K, 4K) in 2 ears, and flat, convex, and up-sloping in 1 ear each. Among the 15 ears in the other high-intensity sound group, the audiometric pattern was C^5-dip in 5 ears, flat in 4 ears, gradually down-sloping in 3 ears, and sharply down-sloping, convex, and up-sloping in 1 ear each. The most common type was C^5-dip in both groups.

Overall Hearing Improvement Levels

Because most patients with acute acoustic hearing disorder experience hearing loss mainly in the high-pitch range, the

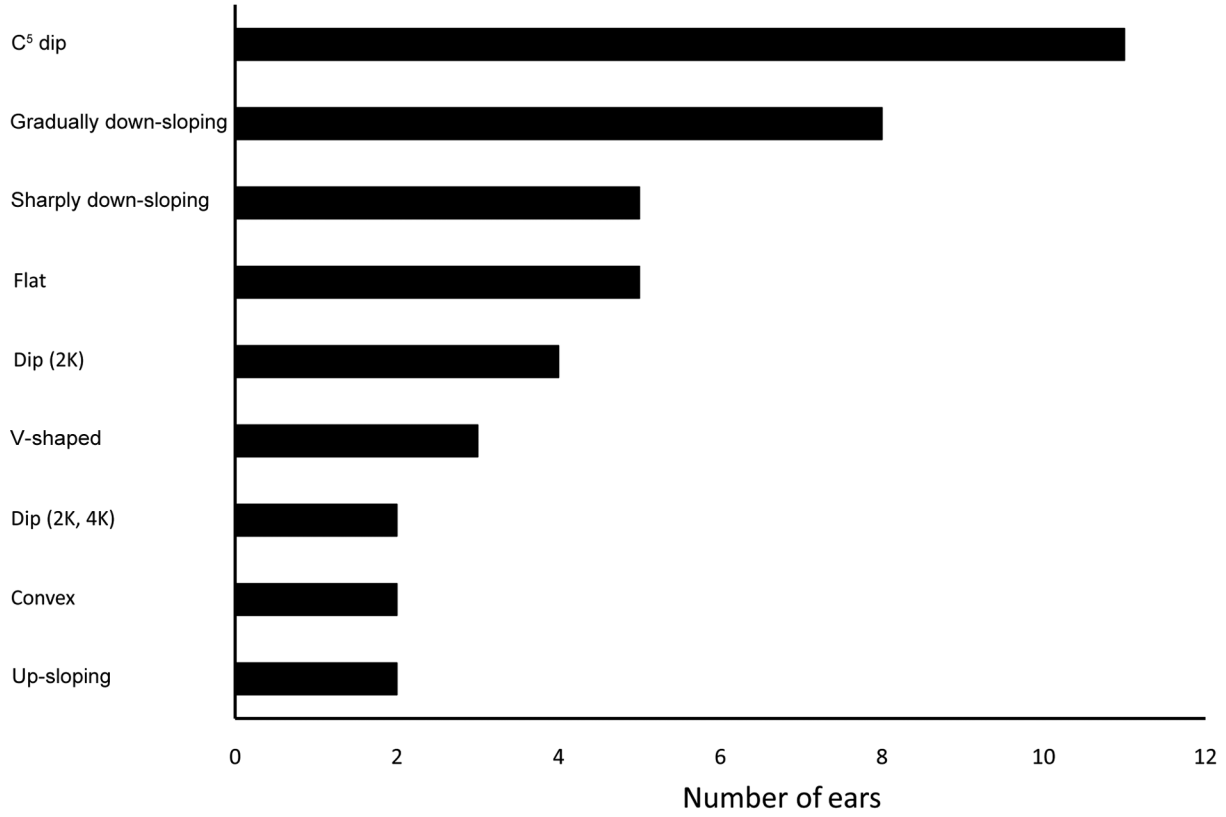

Fig. 4 Audiometric patterns. The most common type was C^5-dip, followed by gradually down-sloping, sharply down-sloping, flat, and so on.

level of hearing improvement by audiometric pattern was evaluated based on the criteria for hearing recovery from sudden deafness with some modifications. Hearing loss was considered cured (resolved) when (1) the arithmetic mean at the frequencies where hearing loss was detected returned to within 20 dB and (2) the hearing acuity of the affected ear improved to a level comparable to that of the unaffected ear, if auditory acuity of the unaffected ear was considered stable; markedly recovered when the arithmetic mean at the frequencies where hearing loss was detected improved by $\geq$30 dB; recovered when the arithmetic mean at the frequencies where hearing loss was detected improved by 10 to 29 dB; and unchanged when the arithmetic mean at the frequencies where hearing loss was detected was within $\pm$9 dB.

The overall level of hearing improvement was considered cured in 17 ears (40.5%), markedly recovered in 5 ears (11.9%), recovered in 8 ears (19.0%), and unchanged in 12 ears (28.6%; ►**Fig. 5**).

Hearing Improvement Level by Audiometric Patterns

The proportions (percentages) of ears showing recovered or a better improvement level by the audiometric pattern were, 11/11 ears (100%) of C^5-dip type, 4/8 ears (50.0%) of gradually down-sloping type, 3/5 ears (60.0%) of sharply down-sloping type, 3/5 ears (60.0%) of flat type, 4/4 ears (100%) of dip (2K) type, 3/3 ears (100%) of V-shaped type, 1/2 ears (50%) of dip (2K,4K) type, 1/2 ears (50.0%) of convex type, and 0/2 ears (0%) of up-sloping type. The C^5-dip, dip (2K), and V-shaped types were associated with better hearing improvement levels (►**Fig. 6**).

Hearing Improvement Level by Age

The hearing improvement level was compared between patients who were younger than 30 years and the patients who were $\geq$30 years because the mean and median ages of the patients in this study were 34.7 years and 27 years, respectively. Among the 27 ears in the <30 years group, the hearing disorder was cured in 17 ears (63.0%), markedly recovered in 4 ears (14.8%), recovered in 4 ears (14.8%), and unchanged in 2 ears (7.4%). Among the 15 ears in the $\geq$30 years group, hearing disorder was cured in 0 ears, markedly recovered in 1 ear (6.7%), recovered in 4 ears (26.7%), and unchanged in 10 ears (66.7%). The hearing improvement level in the <30 years group was significantly ($p < 0.001$) better than that in the $\geq$30 years group (►**Fig. 7**).

Hearing Improvement Level by the Number of Days between Onset and First Visit

The hearing improvement level was compared between ears for which treatment was initiated within 4 days after onset and those for which treatment was initiated $\geq$8 days after onset. There were no cases in which treatment was initiated between day 5 and day 7 after onset.

Among the 33 ears for which the number of days between onset and first visit was within 4 days, hearing disorder was

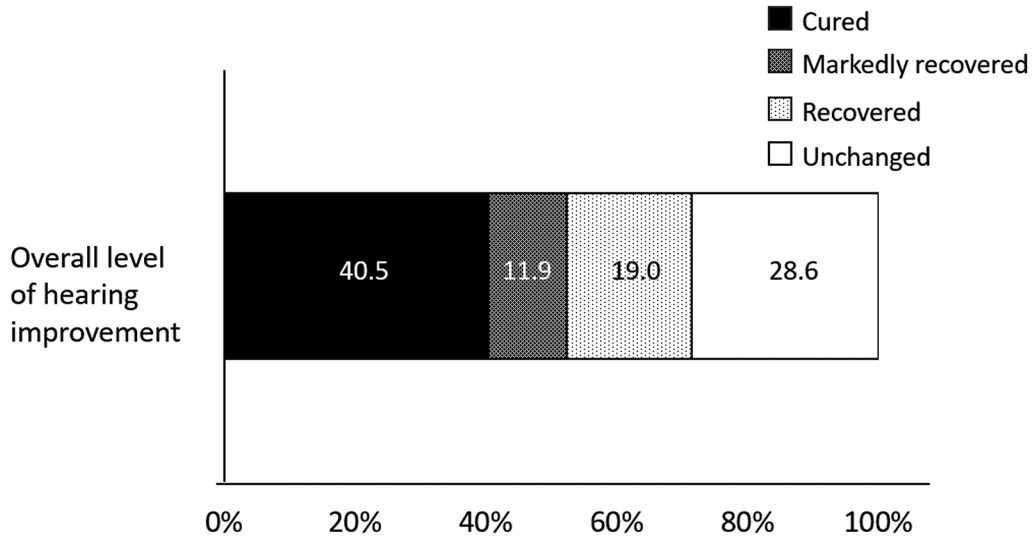

Fig. 5 Overall hearing improvement levels. The overall level of hearing improvement was considered cured in 17 ears (40.5%), markedly recovered in 5 ears (11.9%), recovered in 8 ears (19.0%), and unchanged in 12 ears (28.6%).

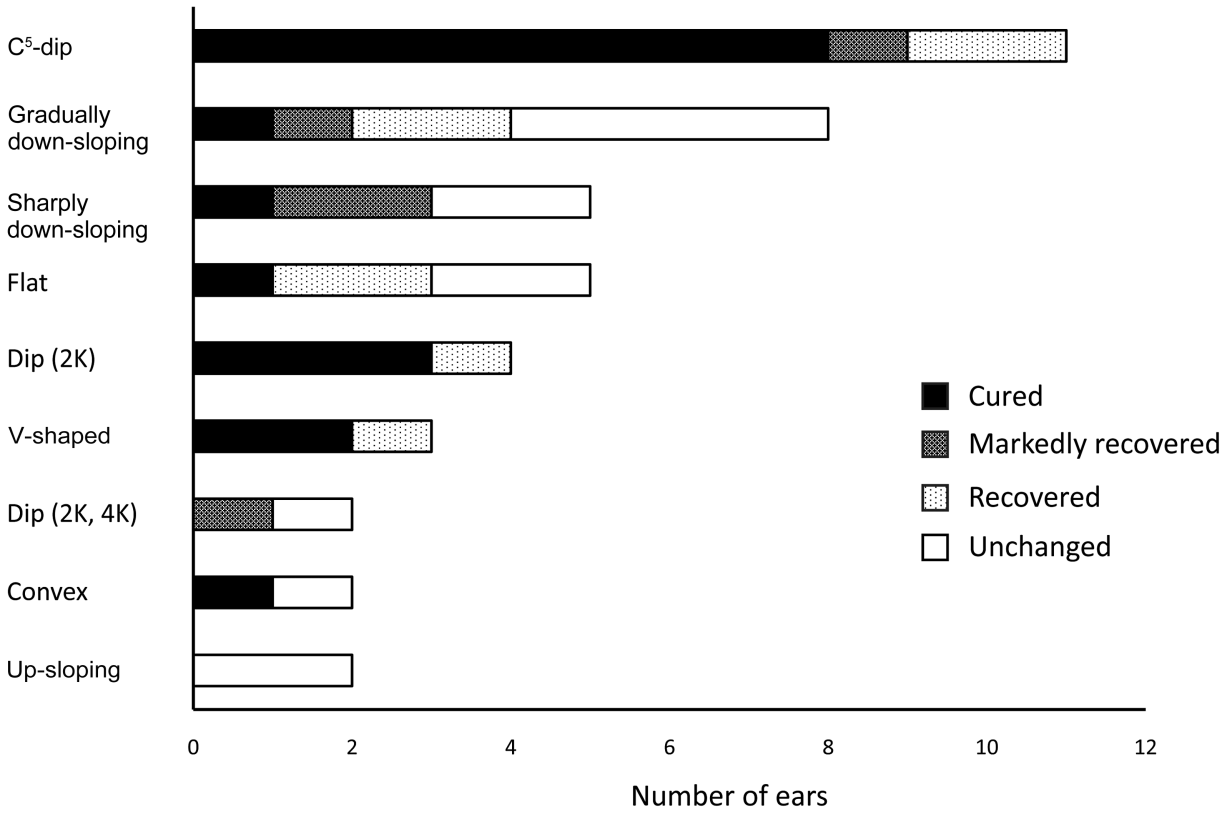

Fig. 6 Hearing improvement level by audiometric patterns. The C^5-dip, dip (2K), and V-shaped types were associated with better hearing improvement levels.

cured in 16 ears (48.5%), markedly recovered in 5 ears (15.2%), recovered in 6 ears (18.2%), and unchanged in 6 ears (18.2%). Among the nine ears for which the number of days between onset and first visit was ≥8 days, hearing disorder was cured in one ear (11.1%), markedly recovered in none of the ears, recovered in two ears (22.2%), and remained unchanged in six ears (66.7%). The hearing improvement level in the ≤4 days group was significantly ($p < 0.01$) better than that in the ≥8 days group (►**Fig. 8**).

Hearing Improvement Level by Laterality: Unilateral versus Bilateral

Among the 28 ears with unilateral acute hearing disorders (17 ears in the shooting group and 11 ears in the other

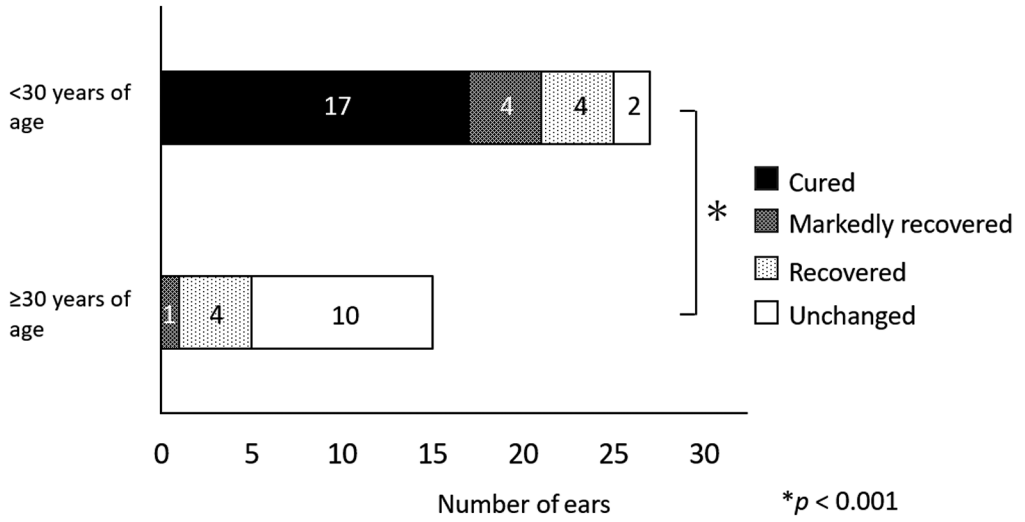

Fig. 7 Hearing improvement level by age. The hearing improvement level in the <30 years group was significantly ($p < 0.001$) better than that in the within ≥30 years group.

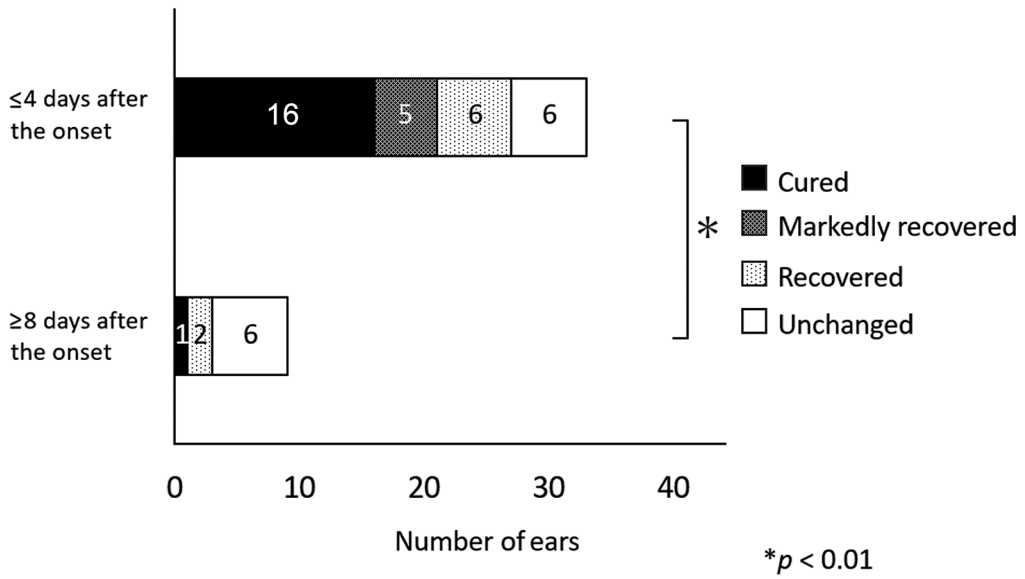

Fig. 8 Hearing improvement level by the number of days between onset and first visit. The hearing improvement level in the ≤4 days group was significantly ($p < 0.01$) better than that in the ≥8 days group.

high-intensity sound group), hearing disorder was cured in 8 ears (28.6%), markedly recovered in 3 ears (10.7%), recovered in 6 ears (21.4%), and unchanged in 11 ears (39.3%). Among the 14 ears with bilateral acute hearing disorder (10 ears in the shooting sound group and 4 ears in the other high-intensity sound group), hearing disorder was cured in 9 ears (64.3%), markedly recovered in 2 ears (14.3%), recovered in 2 ears (14.3%), and unchanged in 1 ear (7.1%). The hearing improvement level in the bilateral group was significantly ($p < 0.05$) better than that in the unilateral group (►**Fig. 9**).

Hearing Improvement Level by Cause: Shooting versus Other High-Intensity Sound Groups

Among the 27 ears in the shooting sound group, hearing disorder was cured in 12 ears (44.4%), markedly recovered in 5 ears (18.5%), recovered in 6 ears (22.2%), and unchanged in 4 ears (14.8%). Among the 15 ears in the other high-intensity sound group, hearing disorder was cured in 5 ears (33.3%), recovered in 2 ears (13.3%), and unchanged in 8 ears (53.3%). The hearing improvement level in the shooting sound group tended to be better than that in the other high-intensity sound group; however, the difference was not significant (►**Fig. 10**).

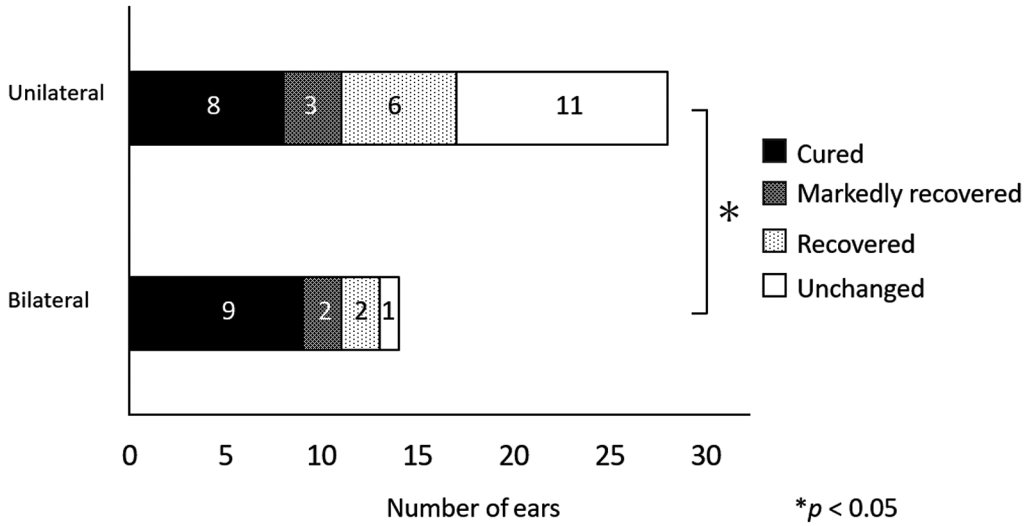

Fig. 9 Hearing improvement level by laterality: unilateral versus bilateral. The hearing improvement level in the bilateral group was significantly ($p < 0.05$) better than that in the unilateral group.

Discussion

Hearing disorders acutely caused by exposure to sounds can be divided into the following: (1) acute acoustic trauma (acute hearing impairment caused by unexpected exposure to sudden high-intensity sounds, such as those produced by an unexpected gunshot near an ear and an explosion of gunpowder), (2) acute acoustic hearing loss (acute hearing impairment caused by predicted, short-term exposure to high-intensity sounds, such as rock music and a gunshot by patient him/herself), and (3) occupational sudden hearing loss (hearing impairment suddenly occurring after long-term occupational exposure to noises).[5] The largest proportion of patients included in this study was accounted for by defense forces personnel who developed acute noise-induced hearing loss during shooting practice.

Temporary/reversible hearing threshold shifts that are caused by sound exposure and recover within a certain duration after sound exposure are referred to as noise-induced temporary threshold shifts (NITTSs). NITTSs usually recover within several minutes to 16 hours, and NITTSs that take >16 hours to recover are called delayed-recovery NITTSs.[6] Meanwhile, irreversible hearing threshold shifts caused by sound exposure are referred to as noise-induced permanent threshold shifts (NIPTSs). In general, NITTSs are not caused by exposure to sounds below 85 dB sound pressure level (SPL) and do not damage auditory apparatuses.[7] Animal experiments have also demonstrated that exposure to sounds ≤80–90 dB does not cause irreversible cochlear changes; however, sounds >90 dB damage cochlear tissues; the tissue damage increases in proportion to the product of the sound intensity and exposure duration, and morphological damage occurs in

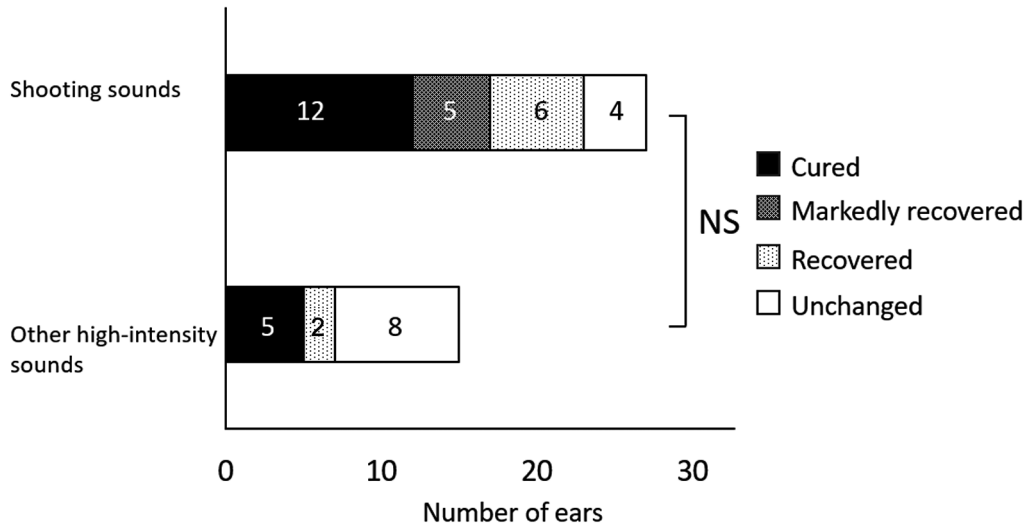

Fig. 10 Hearing improvement level by cause: shooting versus other high-intensity sound groups. The hearing improvement level in the shooting sound group tended to be better than that in the other high-intensity sound group; however, the difference was not significant.

addition to metabolic damage. Exposure to sounds ≥130 dB even for a short duration reportedly causes cochlear changes primarily in its morphology.[8]

Regarding the frequency characteristics of sounds, exposure to sounds with frequencies skewed toward a higher range tends to cause more severe morphological auditory damage and has a higher risk than exposure to sounds in a lower frequency range.[9] Moreover, the inner ear is susceptible to impulsive noises than it is to usual noises because impulsive noises have a very short duration and a high peak SPL, and inner ear protection mechanisms, such as the stapedial reflex, are ineffective because of latency.[10] In addition to the direct effects of shooting sounds, patient factors related to individual differences are considered to contribute to hearing loss caused by exposure to shooting sounds.[3] The individual differences depend on intrinsic factors, such as susceptibility of the inner ear to damage and aging, and extrinsic factors, such as physical fatigue, insufficient sleep, mental stress, and excessive alcohol consumption.[8]

Rock music has a peak SPL ranging from 90 to 110 dB, a loudness level that remains high over time, and a frequency distribution pattern with a main component ≤500 Hz. Thus, it is primarily associated with dip- and up-sloping types. Meanwhile, shooting sounds from rifles have a peak SPL of 160 to 170 dB, a duration of 0.3 to 0.4 seconds, and a main component of around 1,000 Hz.[11] Therefore, the most common audiometric pattern among defense forces personnel with hearing disorders due to exposure to shooting sounds was the sharply down-sloping type.[1,3] Harada et al[1] speculated on the reasons why the dip type is less common among patients with hearing disorders caused by exposure to shooting sounds than among patients with hearing disorders due to other causes, such as exposure to noises and rock music, as follows: exposure to shooting sounds was more commonly associated with the sharply down-sloping type, which represents a more severe disorder than the dip type because hearing disorder due to exposure to shooting sounds is attributable to momentary, high-intensity sounds with a high SPL. In this study, the C^5-dip type was most common in both the shooting and high-intensity sound groups. Moreover, sharply down-sloping type was not observed even among the seven patients who were exposed to shooting sounds without earplugs. Possible reasons for this result include the sound-shielding effect of earplugs in patients who were using earplugs and individual differences.

The incidence of hearing loss due to exposure to shooting sounds is probably higher among ears without an earplug; however, when both ears are under the same condition (i.e., both ears have earplugs or both ears do not have earplugs), the left ear is more susceptible to damage because shooting sounds are emitted at the gunpoint, and thus, the left ear of a person holding their rifle on their right side is closer to the gunpoint.[10] Therefore, the left ear is damaged more often in right-handed people, and the right ear is damaged more often in left-handed people. In our cases, 10, 7, and 5 patients had hearing disorders in the left ear, the right ear, and both ears, respectively. Moreover, of the four patients whose dominant hand was known (all were right-handed), three had a hearing disorder in the left ear, and one had a hearing disorder in the right ear without an earplug. Although we could not confirm the dominant hand of all patients, the results appear to be consistent with the aforementioned theory because right-handedness is generally more common.

Patients with acute acoustic trauma often have a poor prognosis, and patients with acute acoustic hearing loss are likely to achieve some levels of hearing improvement.[12] Previous studies have shown that treatments initiated within 7 days after injury were significantly more effective, and treatment initiation immediately after injury is advisable.[2,3,13] However, hearing loss was cured in a case in which treatment was initiated 39 days after injury, indicating that treatment should be performed even when the patient visits the clinic a long time after injury.[3] By age, many patients aged ≤20 years were cured, whereas patients aged ≥30 years had a poor prognosis. In terms of frequency, mid-frequency hearing loss is more likely to recover than high-frequency hearing loss (particularly 8 kHz).[3] In terms of laterality, a previous report has shown that patients with bilateral hearing disorder tended to have a poorer prognosis than those with unilateral hearing disorder,[10] whereas another study has shown that the cure rate in bilateral cases was higher than that in unilateral cases.[14] In terms of audiometric pattern, V-shaped and dip types are associated with a favorable prognosis.[14,15] Among our cases, the recovery rate in cases where treatment was initiated early was higher, and the hearing improvement level in patients <30 years was better. Moreover, the prognosis was better in bilateral than in unilateral cases, and the C^5-dip, dip (2K), and V-shaped patterns were associated with better hearing improvement levels. These results are similar to those reported previously. Furthermore, the reasons why the degree of hearing improvement in the shooting sounds group tended to be better than that in the other high-intensity sound group, although the difference was not of significance, were that there were more young patients in the shooting sound group, the number of days between onset and first visit was shorter in the shooting sound group, and the sound-shielding effect of earplugs in patients who were using earplugs and individual differences.

Conclusion

We conducted a clinical study of 35 patients (42 ears) with acute acoustic hearing loss who visited the outpatient clinic of the Department of Otorhinolaryngology of Himeji St. Mary's Hospital during 12 years from January 2012 to the end of December 2023. Patients' ages ranged from 16 to 81 years, with the largest number of patients in their 20s. The mean and median ages were 34.7 and 27 years, respectively. There were 27 male and 8 female patients, and approximately 80% of the patients were men. The cause was exposure to shooting sounds in 22 cases and exposure to other high-intensity sounds in 13 cases. In the shooting sound group, the mean age was significantly lower and the number of days between onset and first visit was significantly lower than

those in the other high-intensity sound group. Hearing loss due to exposure to shooting sounds tended to occur more commonly in the ear without an earplug and the left ear. The most common audiometric pattern was C^5-dip (11 ears), followed by gradually down-sloping, sharply down-sloping, flat, dip (2K), and other types. The overall hearing improvement was as follows: cured in 40.5%, markedly recovered in 11.9%, recovered in 19.0%, and unchanged in 28.6%. The C^5-dip, dip (2KHz), and V-shaped audiometric patterns were associated with better hearing improvement levels. The hearing improvement level was significantly better in ears of patients younger than 30 years, ears with a shorter duration between onset and first visit, and ears with bilateral hearing disorders.

Conflict of interest
None declared.

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