



## Original Article

# Comparison of Long-Term Outcome of Intratympanic Dexamethasone Therapy between Acute Noise-Induced Tinnitus and Acute Idiopathic Tinnitus

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**OBJECTIVE:** To compare the long-term outcomes of acute noise-induced tinnitus (ANT) and acute idiopathic tinnitus (AIT) to intratympanic dexamethasone (ITD) therapy.

**MATERIALS and METHODS:** Patients treated for tinnitus occurring immediately after noise exposure comprised the ANT group (n=20) and patients treated for idiopathic tinnitus comprised the AIT group (n=39). All patients were treated with ITD within 3 months of the onset of tinnitus. Quantitative assessment of the improvement in tinnitus using questionnaires and changes in hearing thresholds were compared between the two groups.

**RESULTS:** Mean follow-up durations were 75.90±69.83 weeks in the ANT group and 93.41±101.43 weeks in the AIT group. Patients with ANT were younger in age than those with AIT (38.30±18.28 vs. 53.56±14.08, p=0.00) and were predominately male (Male: Female, M:F 13:7 vs. 13:26, p=0.02, respectively). The subjective tinnitus loudness, time of tinnitus awareness, and Tinnitus Handicap Inventory score improved in both groups, although the changes in these parameters were not significantly different between the groups. The cure and overall improvement rates of the ANT group were 10.00% and 25.00%, respectively. The cure and overall improvement rates of the AIT groups were 25.64% and 35.90%, respectively and there were no significant differences between the two groups in terms of the cure and overall improvement rates (p=0.19 and 0.40, respectively).

**CONCLUSION:** The long-term outcome in terms of control of tinnitus with ITD in the ANT group was similar to that in the AIT group. Thus, ITD injection may be a useful treatment option for acute tinnitus caused by noise trauma.

**KEYWORDS:** Noise, tinnitus, tympanic membrane, dexamethasone

## INTRODUCTION

Noise is a common cause of cochlear damage leading to hearing loss or tinnitus<sup>[1-3]</sup>. The mechanism of noise-induced damage of the cochlea is a combination of mechanical and metabolic injuries. Cochlear exposure to intense sounds can cause excessive movement of the tectorial membrane, resulting in loss of contact between the stereocilia on the hair cells and the tectorial membrane, and separation of the tip links between stereocilia, leading to a disturbance in signal transduction<sup>[4,5]</sup>. Metabolic injury can be caused by reactive oxygen species accumulation<sup>[6-8]</sup>, cochlear ischemia followed by reperfusion injury<sup>[9]</sup>, and excitotoxicity of auditory neurons induced by excessive release of the cochlear afferent neurotransmitter<sup>[10]</sup>. Mechanical destruction of outer hair cells also results in endolymph inflow into the organ of Corti, causing intracellular osmotic change and necrosis<sup>[11]</sup>.

Tinnitus is the most common symptom caused by acoustic trauma, regardless of whether hearing loss is documented alongside<sup>[12,13]</sup>. The correlation reported between the severity of tinnitus and degree of accompanying hearing loss depends on the investigator<sup>[3,13]</sup>. In many cases, patients consider tinnitus to be even more disabling than hearing impairment, or they suffer from tinnitus without any discomfort or sense of hearing disturbance<sup>[14]</sup>. However, the impact of tinnitus induced by acoustic trauma is underestimated unless it is accompanied with hearing impairment. In such cases, the outcome of acoustic trauma treatment has been reported in relation to the recovery of hearing rather than of the tinnitus<sup>[15-17]</sup>. Although no treatment option has been documented to be highly effective for treating acoustic trauma, steroid therapy is widely accepted for the treatment of sudden sensorineural hearing loss (SNHL) and could be effective for acute noise-induced tinnitus (ANT).

We recently reported a randomized controlled trial studying the feasibility of intratympanic dexamethasone (ITD) therapy for the treatment of acute idiopathic tinnitus (AIT) within 3 months of its onset, not accompanied by sudden SNHL<sup>[18]</sup>. With the same ratio-

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nale, we used ITD therapy to treat ANT. We collected data from medical records of patients who were treated with ITD for acute tinnitus, either induced by noise or of unknown cause, and analyzed the treatment outcomes over a relatively long-term follow-up period until the final questionnaires and audiogram were completed. In this study, we compared the clinical characteristics and the long-term outcome of ITD between patients with ANT and those with AIT.

## MATERIALS and METHODS

### Study Design and Subjects

We conducted a retrospective review of the medical records of all patients who were treated with ITD for acute tinnitus (i.e., within 3 months of onset) at a tertiary referral center and who completed follow-up questionnaires and underwent audiometry at least 3 months after treatment. The subjects were excluded when they met the following criteria based on medical records: 1) History of ototoxic drug use or otologic disease, 2) Familial history of hearing loss, 3) Prior steroid use before treatment with ITD, 4) The presence of chronic otitis media, Meniere's disease, or retrocochlear lesion, and 5) Possible somatic tinnitus or objective tinnitus. We also excluded patients with acute subjective tinnitus accompanied by sudden SNHL, defined as  $\geq 30$  dB over 3 contiguous audiometric frequencies in  $< 72$  h. A total of 59 patients with acute tinnitus who met all the criteria and completed questionnaires and pure-tone audiometry at the initial and final visits after ITD treatment were included. They were divided into two groups based on the etiology of tinnitus, including 20 patients whose tinnitus began immediately after noise exposure (ANT group) and 39 patients with idiopathic tinnitus (AIT group). All patients also completed specific questionnaires regarding tinnitus severity and underwent audiological tests including pure-tone audiometry, speech audiometry, impedance audiometry, psychophysical measurement for subjective pitch of tinnitus, and distortion products of otoacoustic emissions. This study was approved by the Institutional Review Board.

### Treatment Protocol

Intratympanic dexamethasone was administered four times on four consecutive days. After confirming the tympanic membrane was normal, local anesthesia was induced using 10% lidocaine spray (Xylocaine Pump Spray; AstraZeneca, Södertälje, Sweden) for 10 min. Patients were placed in a supine position with their heads turned approximately  $45^\circ$  towards the unaffected side. Then, 0.4–0.6 mL of dexamethasone (5 mg/mL; Yuhan, Seoul, Korea) was injected into the middle ear using an operating microscope. Patients were instructed to refrain from changing position, swallowing, or talking for 30 min after the injection to prevent the steroid from leaking through the Eustachian tube.

### Outcome Measures

The Tinnitus Handicap Inventory (THI) [19], questionnaires to assess subjective tinnitus loudness and tinnitus duration, and pure-tone audiometry were completed for all 59 patients at the initial pre-treatment visit and the final post-treatment follow-up visit. Subjective improvement in tinnitus was measured by determining changes in the following four variables: 1) Global improvement (GI) in tinnitus severity (grade 1, markedly worse; grade 2, somewhat worse; grade 3, marginally worse; grade 4, same; grade 5, marginally better; grade

6, somewhat better; grade 7, markedly better; grade 8, completely disappeared); 2) Subjective tinnitus loudness as measured by a visual analog scale (VAS), where 0=no tinnitus and 10=the loudest tinnitus imaginable; 3) Tinnitus awareness score, defined as the percentage of time (in 10% intervals) the patient was aware of tinnitus within one day; and 4) THI. The differences in each variable measured at the initial visit (before treatment) and at the final visit after treatment were analyzed. We defined cure as complete resolution of acute tinnitus or a GI of grade 8 together with changes in VAS for tinnitus loudness, tinnitus awareness score, and THI to 0 after ITD treatment. No improvement was defined as 1) a GI grade  $\leq 4$ , 2) an increase or a  $\leq 2$ -point decrease in the VAS for tinnitus loudness, 3) an increase or a  $\leq 10\%$  decrease in the tinnitus awareness score, or 3) an increase or a  $\leq 20$ -point decrease in THI. Patients not satisfying the criteria for cure or no improvement were considered to show partial recovery. The improvement rate was calculated as the sum of the cure rate and the partial recovery rate.

We compared the therapeutic efficacy of ITD between the two groups by analysis of the following variables: cure rate, improvement rate, GI, mean changes in tinnitus loudness, tinnitus awareness score, and THI score.

### Audiometry Results Analysis

The Asymmetric hearing threshold was defined as 1) a hearing threshold discrepancy of  $> 10$  dB on at least two consecutive frequencies or a discrepancy of  $> 20$  dB on at least one frequency, as determined by pure-tone audiograms; and 2) a hearing threshold of the tinnitus-affected ears (TEs) greater than that of the non-tinnitus ears (NTEs). In the cases showing asymmetric thresholds on pre-treatment audiometry, the comparison with post-treatment hearing thresholds was performed and audiometric response was decided. Audiometric response was defined as a hearing threshold recovery of  $> 15$  dB at any frequency of the pure-tone audiogram.

### Statistical Analysis

Paired t-tests and Wilcoxon tests were used to compare the pre- and post-treatment mean VAS for tinnitus loudness, mean tinnitus awareness score, mean THI score, and mean pure-tone average. Pearson's  $\chi^2$  test and Fisher's exact test were used to compare side, sex, cure rate, and improvement rate between patients in the ANT and AIT groups. The independent t-test and Mann-Whitney U-test were used to compare age, GI, change of VAS, change of tinnitus awareness score, change of pure-tone average, and change of THI between the two groups. To determine which factors could influence symptom improvement, multiple linear regression analyses of the improvement rate were performed with various factors: pure-tone average of the affected side, tinnitus duration, initial tinnitus loudness, initial tinnitus awareness score, and initial THI. Statistical Package for the Social Sciences for Windows version 18.0 (SPSS Inc.; Chicago, IL, USA) was used for all data analyses. Values of  $p < 0.05$  were considered statistically significance.

## RESULTS

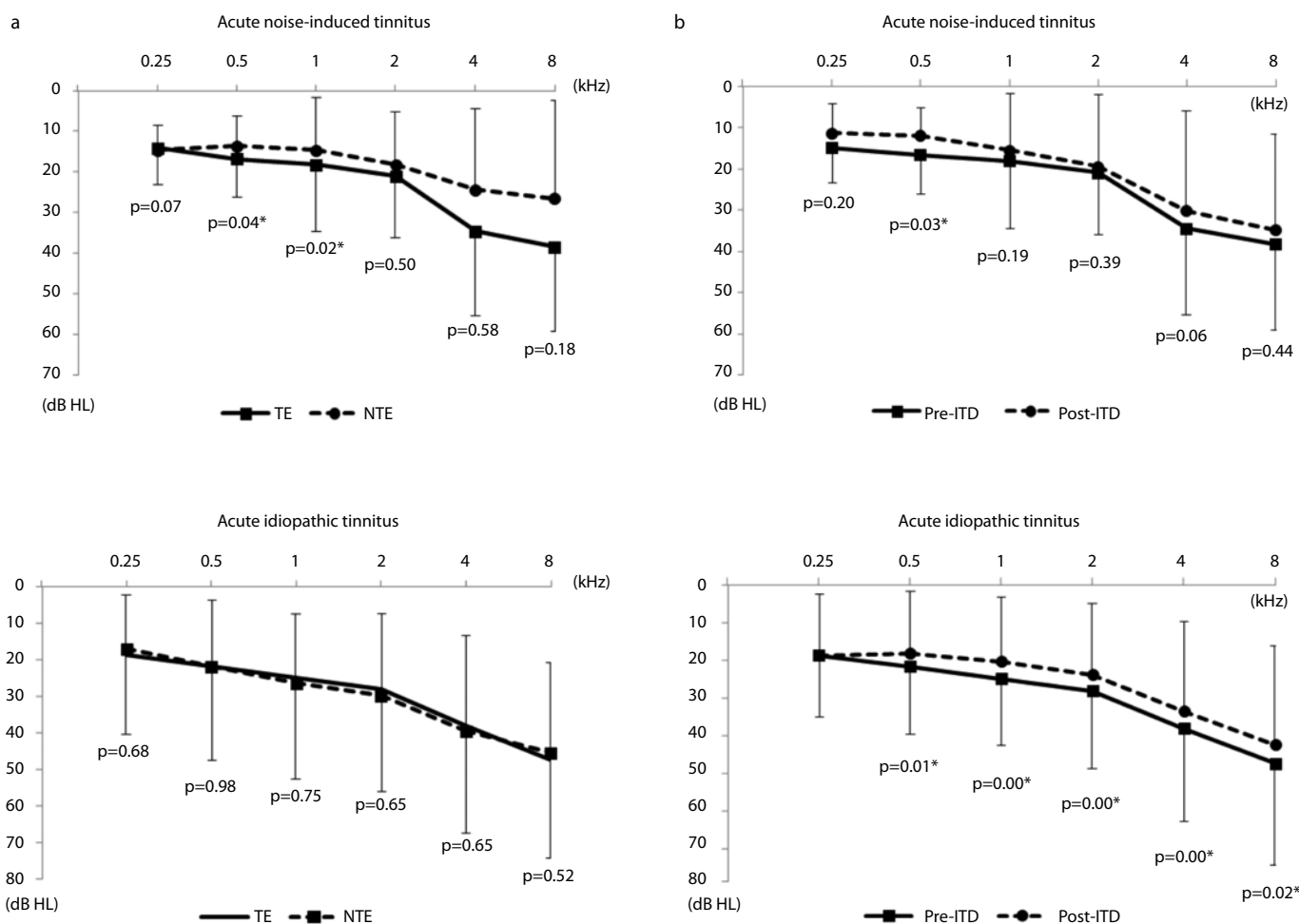
### Patient Characteristics and Audiometric Data

The Male: Female ratio was 13:7 in the ANT group and 13:26 in the AIT group, a statistically significant difference ( $p=0.02$ ). The mean age

**Table 1.** Comparison of age, sex, laterality, and pure-tone average between the ANT and AIT groups

Sex	ANT group (n=20)		AIT group (n=39)		p	
	M:13	F:7	M:13	F:26	TE	NTE
Age (years)	38.30±18.28	53.56±14.08	0.00*			
Laterality of tinnitus	L:11	R:9	L:24	R:15	0.91	
PTA (dB hearing level)	TE	NTE	TE	NTE	TE	NTE
	22.68±13.68	17.68±11.83	28.33±16.93	29.46±25.31	0.05	0.01

ANT: acute noise-induced tinnitus; AIT: acute idiopathic tinnitus; TE: tinnitus ear; NTE: non-tinnitus ear; PTA: pure-tone average



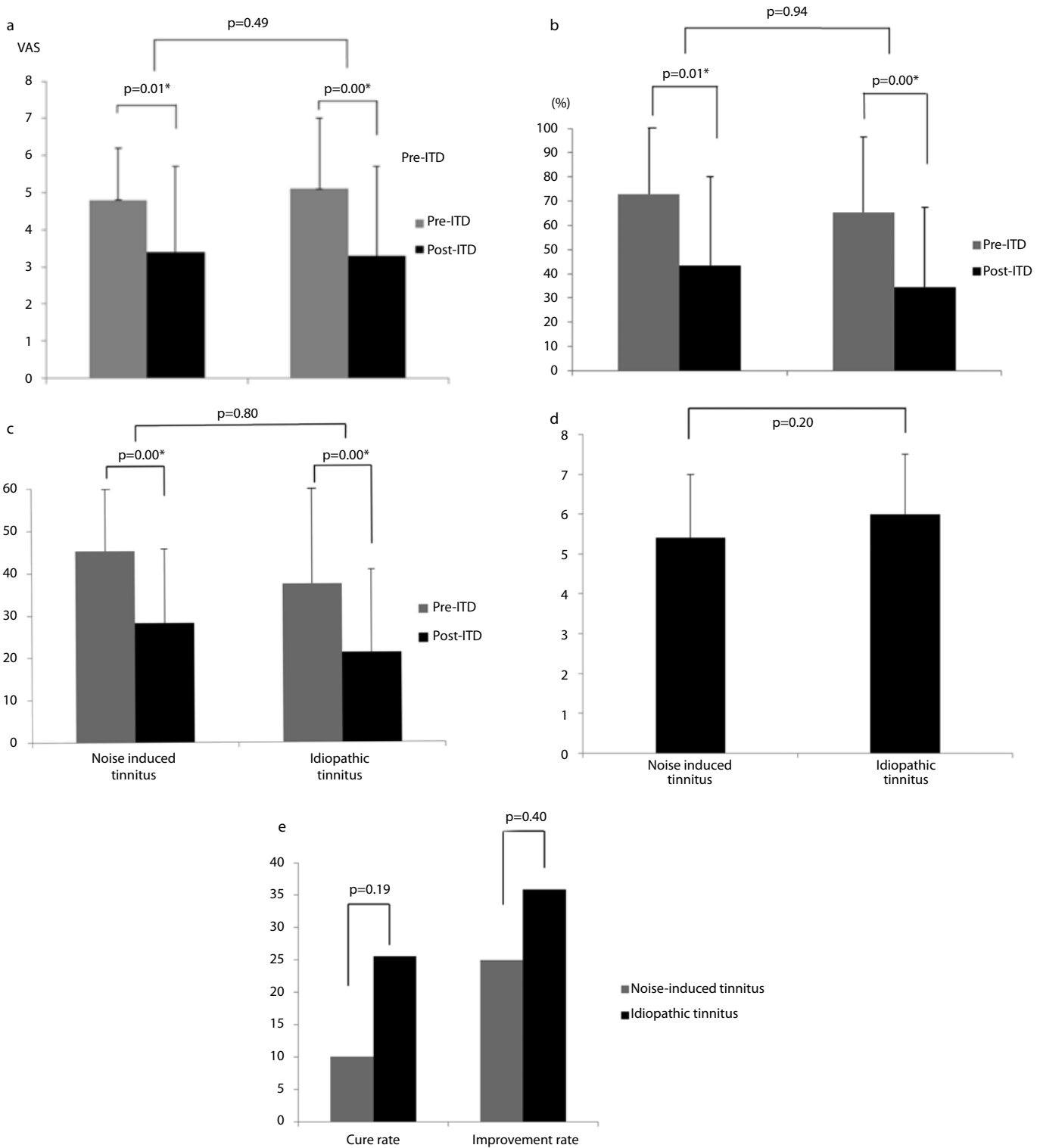
**Figure 1. a, b.** Mean pure-tone threshold in audiometry in the acute noise-induced tinnitus (ANT) and acute idiopathic tinnitus (AIT) groups. In the comparison of mean pure-tone threshold at each measured frequency between tinnitus-affected ears (TEs) and non-tinnitus ears (NTEs), there was a statistical difference at 0.5 kHz and 1 kHz in the ANT group and no differences at any frequency in the AIT group (a). Changes in mean pure-tone thresholds after treatment. In the TEs of the ANT group, there was no significant improvement in the mean threshold except at 0.5 kHz; whereas the TEs of the AIT group, there were significant improvements at all measured frequencies except at 0.25 kHz (b).

of patients with ANT was significantly younger than those with AIT (38.30±18.28 vs. 53.56±14.08 years, p=0.00). Of the 20 patients with ANT, the right ear was affected in 9 and the left ear in 11. In the 39 patients with AIT, the right ear was affected in 15 and the left ear in 24. There was no statistically significant difference in laterality between the two groups (p=0.91, Table 1). The initial pure-tone averages in the ANT group were 22.68±13.68 dB HL in TEs and 17.68±11.83 dB HL in NTEs, compared with 28.33±16.93 dB HL in TEs and 29.46±25.31 dB HL in NTEs in the AIT group (Table 1). The mean pure-tone threshold differed significantly at 0.5 kHz and 1 kHz (p=0.04 and 0.02) between TEs and NTEs in the ANT group; whereas there were no such significant differences between TE and NTEs at any frequency in the AIT group (Figure 1a).

**Table 2.** Comparison of pre-treatment tinnitus characteristics between the ANT and AIT groups

	ANT (n=20)	AIT (n=39)	p
Symptom duration (days)	34.90±34.18	43.15±26.78	0.153
Pitch (kHz)	5.50±5.44	3.17±2.87	0.176
THI score	45.30±27.05	37.47±23.95	0.263
VAS of tinnitus loudness	4.75±1.37	5.05±1.85	0.523
*TAS (%)	73.00±30.28	65.38±31.19	0.374

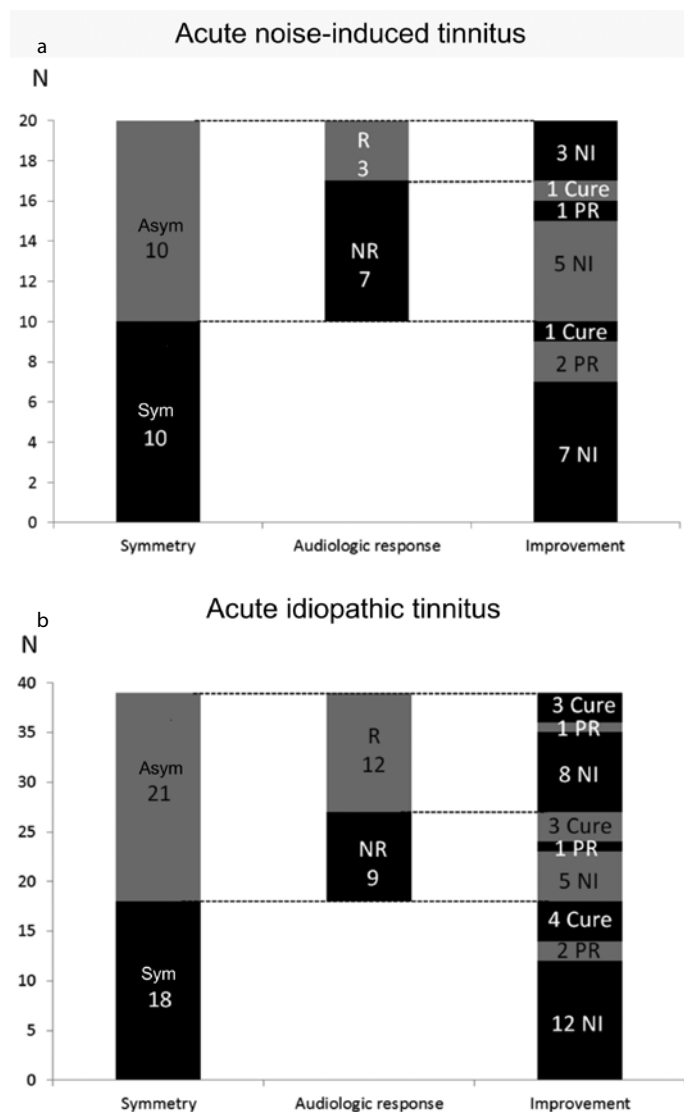
\*TAS is defined as the percentage of the time the patient is aware of tinnitus for a day. ANT: acute noise-induced tinnitus; AIT: acute idiopathic tinnitus; THI: Tinnitus Handicap Inventory; VAS: visual analogue scale; TAS: Tinnitus awareness score



**Figure 2. a-e.** Comparison of treatment outcomes of intratympanic dexamethasone (ITD) therapy between acute noise-induced tinnitus (ANT) and acute idiopathic tinnitus (AIT) groups. The mean tinnitus loudness by the visual analog scale (VAS) (a), the mean tinnitus awareness score (%) (b), and the mean Tinnitus Handicap Inventory score (c) decreased significantly in both groups; there were no significant differences in the changes between the groups. The mean global improvement index also did not differ statistically between the groups (d). Improvement and cure rates for ANT and AIT groups (e). There were no significant differences between the groups.

The mean duration of tinnitus at the initial visit was  $34.90 \pm 34.18$  days in the ANT group (range 4–120 days) and  $43.15 \pm 26.78$  days in the AIT group (range 3–90 days), a non-significant difference between the

two groups ( $p=0.15$ ). None of the pre-treatment variables differed between the two groups, including pitch of tinnitus, THI score, tinnitus loudness score, and tinnitus awareness score (Table 2).



**Figure 3. a, b.** Audiological results and tinnitus-control results in the acute noise-induced tinnitus (a) and acute idiopathic tinnitus (b) groups.

#### Audiometry Results

In the ANT group, the mean pure-tone average in TEs improved from  $22.68 \pm 13.68$  dB HL to  $19.46 \pm 13.72$  dB HL ( $p=0.03$ ) after treatment. In the AIT group, the mean pure-tone average in TEs also improved from  $28.33 \pm 16.93$  dB HL to  $24.13 \pm 16.48$  dB HL ( $p=0.00$ ) after treatment. The mean threshold for each frequency in TEs did not differ significantly between pre- and post-treatment values in the ANT group except at 0.5 kHz; whereas in the AIT group, statistically significant differences were found at all measured frequencies except for 0.25 kHz (Figure 1b).

#### Treatment Outcomes

The mean durations from treatment until the final follow-up questionnaires and audiograms in the ANT and AIT groups were  $75.90 \pm 69.83$  weeks (range 12–269 weeks) and  $93.41 \pm 101.43$  weeks (range 15–287 weeks), respectively, with no significant difference ( $p=0.50$ ).

In the ANT group, the mean tinnitus loudness score decreased significantly, improving from  $4.75 \pm 1.37$  at the baseline to  $3.40 \pm 2.28$

after ITD ( $p=0.01$ ). The mean tinnitus awareness score decreased significantly from  $73.00\% \pm 30.28\%$  at the baseline to  $43.50\% \pm 36.60\%$  after treatment ( $p=0.01$ ). The mean THI score also decreased from  $45.30 \pm 27.05$  at the baseline to  $28.20 \pm 17.49$  after treatment ( $p=0.00$ ). The mean GI grade was  $5.40 \pm 1.60$ . Of the 20 patients with ANT, 2 were cured of tinnitus (10.00%), 3 partially recovered, and 15 did not improve. The overall improvement rate, including both cure and partial recovery, was thus 25.00% (5/20) (Figure 2).

In the AIT group, the mean tinnitus loudness score decreased significantly, improving from  $5.05 \pm 1.85$  at the baseline to  $3.26 \pm 2.39$  after treatment ( $p=0.00$ ). The mean tinnitus awareness score decreased significantly from  $65.38\% \pm 31.19\%$  at the baseline to  $34.62\% \pm 32.92\%$  after treatment ( $p=0.00$ ). The mean THI score also decreased from  $37.47 \pm 23.95$  at the baseline to  $21.16 \pm 19.58$  after treatment ( $p=0.00$ ). The mean GI grade was  $6.03 \pm 1.53$ . Of the 39 patients with AIT, 10 were cured of tinnitus (25.64%), 4 partially recovered, and 25 did not improve. The overall rate of improvement, including cure and partial recovery, was 35.90% (14/39) (Figure 2).

#### Comparisons of the Treatment Outcomes between ANT and AIT Groups

The mean changes in tinnitus loudness, tinnitus awareness, and THI scores after treatment did not differ significantly between the two groups ( $p=0.49$ ,  $p=0.94$ , and  $p=0.80$ , respectively; Figures 2a-c). The mean GI grade also did not differ statistically between the two groups ( $p=0.20$ , Figure 2d). Although the cure rate and overall improvement rates for AIT appeared to be higher than those for ANT (25.64% vs. 10.00% and 35.90% vs. 25.00%, respectively), the differences were not statistically significant ( $p=0.19$  and 0.40, Figure 2e).

On the pre-treatment audiograms of the ANT group, the symmetric threshold:non-symmetric threshold ratio was 10:10. Of the 10 patients with an asymmetric threshold, 3 (30.00%) showed an audiological response (defined as a hearing threshold recovery of  $>15$  dB at any frequency) and 7 showed no response (70.00%) on post-treatment audiometry. Of the 3 responders, none had improvement of tinnitus; whereas of the 7 non-responders, 1 was cured and 1 partially recovered. Of 10 patients with symmetric thresholds at the baseline, 1 was cured of tinnitus and 2 partially recovered (Figure 3a).

On the pre-treatment audiograms for the AIT group, 21 patients had symmetric thresholds and 18 had non-symmetric thresholds. Of the 21 patients with asymmetric thresholds, 12 (57.14%) showed an audiometric response with 3 of them cured of tinnitus and 1 partially recovered. Among the 9 remaining patients (42.86%) who showed no response, 3 were cured and 1 had partially recovered. Of 18 patients with symmetric hearing thresholds at the baseline, 4 were cured of their tinnitus and 2 partially recovered (Figure 3b).

#### Prognostic Factors and Multiple Linear Regression Analysis

Approximately 21.4% and 14.7% of  $R^2$  for the models for the improvement rate were explained by clinically relevant factors including pure-tone average of the affected side, tinnitus duration, initial tinnitus loudness, initial tinnitus awareness score, and initial THI in the ANT and AIT groups, respectively (Table 3). No clinical variable was found to be associated with improvement of tinnitus ( $p>0.05$ ).

**Table 3.** Multiple linear regression analysis of the improvement rates for various factors in ANT and AIT groups

	Factor	R <sup>2</sup>	Standardized β Coefficient	p
Improvement rate for ANT group	PTA	0.214	0.155	0.563
	Tinnitus duration		-0.260	0.320
	Initial tinnitus loudness		0.382	0.224
	Initial TAS		-0.419	0.188
	Initial THI		0.285	0.302
Improvement rate for AIT group	PTA	0.147	-0.055	0.742
	Tinnitus duration		-0.393	0.028
	Initial tinnitus loudness		0.003	0.987
	Initial TAS		-0.016	0.931
	Initial THI		0.166	0.406

ANT: acute noise-induced tinnitus; AIT: acute idiopathic tinnitus; PTA: pure-tone average; TAS: tinnitus awareness score; THI: Tinnitus Handicap Inventory

**DISCUSSION**

Tinnitus triggered by acoustic trauma has previously been reported to occur more commonly in males and at a relatively young age [12, 20], similar to the findings in our study. This can be explained by the fact that young people more often participate in outdoor activities, such as at rock concerts or while in the military, and have a greater chance of exposure to loud or extreme noises. The subjective pitch of the tinnitus measured psychophysically was higher in the ANT than in the AIT group (5.50±5.44 kHz vs. 3.17±2.87 kHz) even though the difference was not significant. These results are similar to results from previous studies that have reported on high-pitched tinnitus caused by acoustic trauma [21, 22]. The auditory neurons responsible for the tinnitus could fire more than normal because of reduced lateral inhibition at the edge of the characteristic frequency of the damaged hair cells [23, 24]. Given this theory, and the fact that noise usually causes a 4 kHz dip in the audiogram, the average perceived frequency in noise-induced tinnitus of 5.50 kHz is understandable.

Because corticosteroid and mineralocorticoid receptors have been demonstrated in the inner ear in animal models and in the human temporal bone [25, 26], the steroid actions of immune suppression, anti-inflammation, and ion homeostasis would be expected to help the repair of cochlear damage. This is why corticosteroids have been used for a long time as empirical treatments for inner ear diseases, such as sudden SNHL, although such treatment is still controversial [27, 28]. There were several studies trying steroid therapy at an early stage after acoustic trauma. In a study of 52 young soldiers who were exposed to the noise of intense gunfire, 36.5% of subjects showed complete hearing recovery after treatment with steroids and piracetam. But 68.4% of the patients who completely recovered began treatment within the first hour after acoustic trauma, which is quite a narrow window for patients to achieve. Of those treated more than 24 hours after noise exposure, complete hearing recovery occurred in only 13.3% of patients [16]. In another study of 27 patients with acoustic trauma treated with oral steroids, vasodilators, and vitamins, 29.6% of patients, all of whom were treated within 7 days, had a response, including 11.1% with complete hearing recovery [17]. However, in an animal study, cochlear infusion of methylprednisolone for 7 days did not improve hearing in guinea pigs with acoustic trauma [15]. We could not find any studies that reported the prognosis of tinnitus induced by acoustic trauma.

Intratympanic injection of steroids has been used as an alternative to systemic steroids for various inner ear diseases because it has comparatively fewer systemic side effects. A randomized, large-scale, multicenter study demonstrated that intratympanic corticosteroids have the same efficacy as oral steroids for the treatment of sudden SNHL [29]. Although many studies have not shown a positive effect of intratympanic steroid on tinnitus, we demonstrated the therapeutic effects of ITD limited to the acute tinnitus cases in a recent double-blind, randomized, and controlled trial [18]. In that study, we administered ITD for acute idiopathic tinnitus that had developed within 3 months before treatment because cochlear damage will be irreversible after 3 months. Although the pathophysiological mechanism of tinnitus in the central auditory system is still unclear, the majority of tinnitus is triggered by cochlear damage. We believe that there is a short therapeutic window to reverse the cochlear damage, and if the administration of ITD is early enough to reverse cochlear damage and subsequent changes in the central auditory system, elimination of tinnitus may be possible. Indeed, the time of treatment is reported to be the only factor associated with the cure of tinnitus [18, 30]. In the current study, we compared the therapeutic efficacy of ITD between ANT and AIT, and although the cure and improvement rates suggested a worse outcome in the ANT group, we found no significant difference between the two groups. The efficacy of ITD in ANT was similar to that in AIT in terms of tinnitus loudness, duration of tinnitus awareness, and tinnitus discomfort. The results imply that the ITD injection could be a treatment option for ANT if its therapeutic effect in AIT, demonstrated in a previous study [18], was true.

In previous studies of the same treatment protocol followed in our clinic, the rate of improvement, including cure and partial recovery, by ITD was about 75% in patients with AIT [18, 30]; whereas in the current study, the rates were lower (35.9% in AIT group and 25.6% in ANT group). The differences in treatment outcome could be explained in several ways. The most important reason is the difference in the length of follow-up. Treatment outcomes in the previous study were assessed at 12 weeks after treatment, whereas in this study, we evaluated patients for a relatively long period of time (75.90±69.83 weeks in the ANT group and 93.41±101.43 weeks in the AIT group). It may be that a large proportion of patients who were cured or improved were lost to follow-up. Another potential reason is that a number of patients whose tinnitus improved were excluded from the study because audiometry was not performed at the same time

as the follow-up symptom questionnaires. We believe that follow-up with pure-tone audiometry is necessary for the assessment in ITD treatment for acute tinnitus because this treatment is conceptually targeted at the restoration of cochlear damage.

In terms of pre-treatment audiometric data, the thresholds were higher at several frequencies in TEs than in NTEs in the ANT group; whereas in the AIT group, thresholds in both TEs and NTEs were similar. However, when comparing pre-and post-treatment audiometric data in the TEs, significantly improved thresholds were found at more frequencies in the AIT group than in the ANT group. The rate of audiometric response on the pure-tone audiogram was higher in the AIT group than in the ANT group (57.14% vs. 30.00%). We speculate that in patients with ANT, the ears with tinnitus were exposed to more severe noise trauma, leading to more hearing impairment on that side than in the contralateral ear without tinnitus. However, recovery from hearing impairment caused by noise trauma seems to be harder to achieve than from idiopathic hearing loss. The improvements in tinnitus and the audiological response (i.e., hearing recovery) were not correlated in either group. Indeed, many cases with improvement in tinnitus were not associated with an audiological response. This finding could be explained if the pathophysiology of tinnitus depends more on plastic changes in the central auditory system rather than on the degree of cochlear damage<sup>[23, 24, 31, 32]</sup>.

This study has several limitations. First, we did not use a control group to rule out a potential placebo effect. However, we identified a therapeutic effect of ITD on AIT compared with a control group in our previous study, so that in this study, we extended the application of ITD to ANT. Second, the length of follow-up until the final assessment varied because we collected the data from a chart review. Third, the sample size of the ANT group was smaller than that of the AIT group.

## CONCLUSION

Acute noise-induced tinnitus occurs frequently in young adult males. The long-term outcome in terms of control of tinnitus with ITD in the ANT group was similar to that in the AIT group, indicating that ITD injection could be a treatment option for ANT. However, the audiological response after ITD was poorer in the ANT group than in the AIT group. Further prospective research with a control group will be needed to test the effectiveness of ITD for acute tinnitus caused by noise trauma.

**Ethics Committee Approval:** Ethics committee approval was received for this study from the Institutional Review Board.

**Informed Consent:** Written informed consent was obtained from patients who participated in this study.

**Author Contributions:** Concept - H.J.S.; Design - H.J.S., Y.H.A.; Supervision - H.J.S.; Resources - E.S.L.; Materials - E.S.L.; Data Collection and/or Processing - E.S.L., D.H.K.; Analysis and/or Interpretation - D.H.K.; Literature Search - E.S.L.; Writing Manuscript - E.S.L., H.J.S.; Critical Review - H.J.S.

**Conflict of Interest:** No conflict of interest was declared by the authors.

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