Original Article

http://dx.doi.org/10.3349/ymj.2014.55.1.19
pISSN: 0513-5796, eISSN: 1976-2437

Yonsei Med J 55(1):19-24, 2014

YMJ

Change in Tinnitus after Treatment of Vestibular Schwannoma: Microsurgery vs. Gamma Knife Radiosurgery

Soon Hyung Park,[1] Hee So Oh,[2] Ju Hyun Jeon,[3] Yong Ju Lee,[2] In Seok Moon,[2] and Won-Sang Lee[2]

[1]Department of Otorhinolaryngology, Keimyung University College of Medicine, Daegu;
[2]Department of Otorhinolaryngology, Yonsei University College of Medicine, Seoul;
[3]Department of Otorhinolaryngology, Inje Univertigy College of Medicine, Ilsan Paik Hospital, Goyang, Korea.

Received: March 12, 2013
Revised: April 14, 2013
Accepted: April 15, 2013
Corresponding author: Dr. In Seok Moon,
Department of Otorhinolaryngology,
Yonsei University College of Medicine,
50 Yonsei-ro, Seodaemun-gu,
Seoul 120-752, Korea.
Tel: 82-2-2228-3627, Fax: 82-2-393-0580
E-mail: ismoonmd@yuhs.ac

· The authors have no financial conflicts of interest.

Purpose: Tinnitus is a very common symptom of vestibular schwannoma, present in 45 to 80% of patients. We evaluated changes in tinnitus after translabyrinthine microsurgery (TLM) or gamma knife radiosurgery (GKS). **Materials and Methods:** Among 78 patients with vestibular schwannoma who underwent TLM or GKS at Severance Hospital from 2009-2012, 46 patients with pre- or postoperative tinnitus who agreed to participate were enrolled. Pure tone audiometry, tinnitus handicap inventory (THI), visual analogue scale (VAS) scores for loudness, awareness, and annoyance were measured before and after treatment. Changes of THI and VAS were analysed and compared according to treatment modality, tumour volume, and preoperative residual hearing. **Results:** In the TLM group (n=27), vestibulocochlear nerves were definitely cut. There was a higher rate of tinnitus improvement in TLM group (52%) than GKS group (16%, p=0.016). The GKS group had a significantly higher rate of tinnitus worsening (74%) than TLM group (11%, p<0.001). Mean scores of THI and VAS scores significantly decreased in the TLM group in contrast to significant increases in the GKS group. Tumor volume and preoperative hearing did not affect the changes in THI or VAS. **Conclusion:** GKS can save vestibulocochlear nerve continuity but may damage the cochlea, cochlear nerve and can cause worsening tinnitus. In cases where hearing preservation is not intended, microsurgery with vestibulocochlear neurectomy during tumor removal can sometimes relieve or prevent tinnitus.

Key Words: Vestibular schwannoma, tinnitus, microsurgery, gamma knife radiosurgery, cochlear nerve

INTRODUCTION

Vestibular schwannoma is a benign lesion derived from the neurilemma sheath and accounts for approximately 6% of newly diagnosed intracranial tumors.[1] Microsurgery and stereotactic radiotherapy are the most widely used treatment modalities for vestibular schwannoma. Patient quality of life after surgery for vestibular schwannoma has been emphasised recently. In addition to sensorineural hearing loss, tinnitus is one of the most common symptoms in vestibular schwannoma patients,[2-4] and

bothersome tinnitus can occur after treatment in some cases. Many theories have been proposed to explain the origin of tinnitus, including tinnitus associated with vestibular schwannoma. Some authors suggest that tinnitus originates in peripheral organs such as the cochlea or cochlear nerve, whereas others propose a central cause such as the cochlear nucleus, brainstem, and cerebral cortex. Some patients still suffer from tinnitus even after tumor removal and vestibulocochlear nerve section, which supports the theory that tinnitus is likely a phantom symptom of central origin.[5-7]

Some authors state that even if the vestibulocochlear nerve is preserved, surgical trauma during treatment of vestibular schwannoma may cause postoperative tinnitus.[8] Ionized radiation used to treat vestibular schwannoma can also cause cochlea and cochlear nerve toxicity[9] and may aggravate tinnitus postoperatively, regardless of hearing preservation.

In this study, we investigated changes in tinnitus in patients who underwent translabyrinthine microsurgery (TLM) and gamma knife radiosurgery (GKS). Factors related to tinnitus, such as pretreatment hearing and tumor volume, were also evaluated.

MATERIALS AND METHODS

We evaluated outcomes of 78 vestibular schwannoma patients who underwent TLM (n=54) or GKS (n=24) and regularly followed at Severance Hospital between January 2009 and December 2012. Among them, 64 patients completed a tinnitus questionnaire. Microsurgery was performed at the Department of Otolaryngology by one senior surgeon via the translabyrinthine approach and tumor was completely or near totally removed in all patients. GKS was performed at the Department of Neurosurgery by the other one senior surgeon. After excluding 12 patients in TLM group and 6 patiens in GKS group who did not have pre- or postoperative tinnitus, 27 patients who underwent surgical removal via TLM and 19 patients who underwent GKS were finally enrolled. In the TLM group, the cochlear nerve was sectioned in all cases and resulted in deafness of operated ear. GKS was performed using the 201 source Cobalt-60 Leksell gamma unit. The tumor margin was covered by the 50% isodose line, and 12-13 Gy was delivered to the margin.

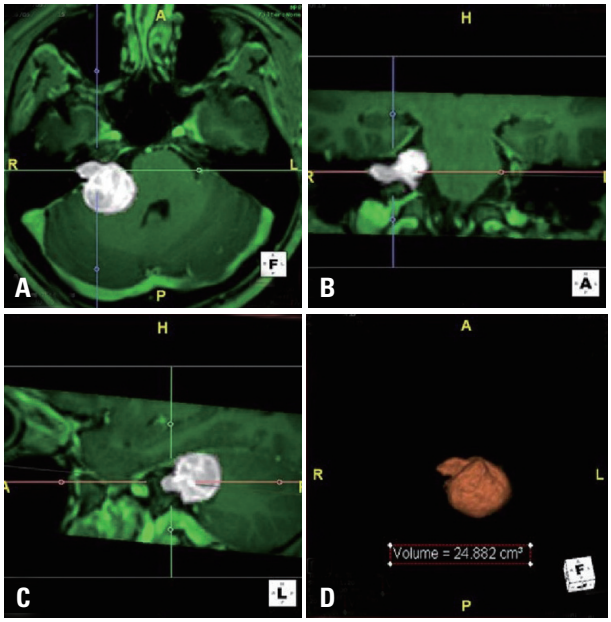


Fig. 1. Tumor volume was measured on magnetic resonance imaging using a three-dimensional reconstruction program (Aquarius iNtuition, TeraRecon). Serial images of axial (A), coronal (B) and sagittal (C) cuts of gadolinium-enhanced temporal MRI were input into the program; (D) the tumor was reconstructed three-dimensionally, and the tumor volume was automatically calculated.

We evaluated preoperative pure tone audiometry, and mean hearing levels were expressed as the average of hearing thresholds at 500, 1000, 2000 and 3000 Hz (4-tone average). Preoperative tumor volume on magnetic resonance imaging was measured using a three-dimensional reconstruction program (Aquarius iNtuition, TeraRecon) (Fig. 1). Tinnitus severity was evaluated using the tinnitus handicap inventory (Supplementary Fig. 1, only online) and visual analogue scale pre- and one month postoperatively. Visual analogue scale was used for loudness (1-10), awareness (1-10), and annoyance (1-10). Change in postoperative tinnitus was defined as change in tinnitus handicap inventory scores of more than 20% and 10 scores positively or negatively, otherwise postoperative tinnitus was defined as unchanged. This study was approved by the Institutional Review Board of Severance Hospital, Yonsei University Health System (4-2012-0910).

Results were analysed using Fisher's exact test, paired t-test, and Pearson correlation test as appropriate. The level of significance was set at p value less than 0.05. Statistical analyses were performed using SPSS v16.0 (SPSS Inc., Chicago, IL, USA).

RESULTS

We evaluated 46 patients including 11 males and 35 females with a mean age of 45.9±11.3 years at treatment. The vestibulocochlear nerve was definitely cut during TLM, but anatomically preserved in the GKS group. Forty three patients had

tinnitus on the side with tumor and three patients had bilateral tinnitus. Mean tumor volume was 5.05±8.68 cm^3 in the TLM group and 4.37±6.91 cm^3 in the GKS group (Table 1).

The ratios of patients with change in tinnitus, based on the tinnitus handicap inventory, are shown in Fig. 2. There was a higher rate of improved patients following TLM than GKS (p=0.016). In fact, the GKS group showed a strong tendency of tinnitus aggravation (p<0.001) (Fig. 2). This tendency was also seen in visual analogue scale (Supplementary Fig. 2, only online).

The mean tinnitus handicap inventory score was significantly reduced from 51.25±24.45 preoperatively to 31.7±30.33 postoperatively in the TLM group (p=0.006). Mean score of visual analogue scale also showed significant decrease in all items of loudness, awareness and annoyance (p<0.05) (Fig. 3). In GKS group, mean score of tinnitus handicap inventory was significantly increased from 15.29±21.47 preoperatively to 41.2±2.58 postoperatively (p<0.001). Mean score of visual analogue scale was significantly increased in items of loudness and annoyance (p<0.05), but not awareness (p=0.061) (Fig. 4).

We also evaluated factors related to tinnitus such as tumor volume and preoperative residual hearing using Pearson's correlation test. Preoperative tinnitus handicap inventory scores did not correlate with preoperative tumor volume (p>0.05). Postoperative tinnitus handicap inventory score and tinnitus handicap inventory change (difference between pre- and postoperative tinnitus handicap inventory scores) did not correlate with preoperative tumor volume in both the TLM and GKS groups (p>0.05). Furthermore, we compared preoperative pure tone audiometry and tinnitus handicap inventory scores to investigate the relationship between preoperative hearing function and postoperative tinnitus handicap inventory score, and found no significant correlation in both groups (p>0.05).

DISCUSSION

There are various results of changes in tinnitus after microsurgery. Kameda, et al.[10] reported that tinnitus disappeared in 25.2%, improved in 33.3%, remained unchanged in 31.6%, and worsened in 9.9% of patients after a retrosigmoid approach. There was no difference in tinnitus incidence based on whether or not the vestibulocochlear nerve was resected during surgery. Schaller, et al.[11] suggested that sudden drop of blood pressure after hearing preserving surgery can be a risk factor for developing tinnitus after microsurgery. Another study reported reduction in tinnitus severity in 45% of patients who underwent the middle cranial fossa approach.[12] Harcourt, et al.[13] investigated change in tinnitus after TLM and reported that patients who had probable or definite cochlear nerve section had significantly lower postoperative tinnitus severity. In addition, it was found that cochlear neurectomy improved tinnitus control rates compared to vestibular nerve section alone.[14] In our study, 52% (14/27) of patients who underwent TLM with vestibulocochlear nerve section showed improved tinnitus.

We have unpublished results on eight patients who underwent tumor removal via middle cranial fossa approach (MCFA) in our hospital at the same period and by the same surgeon. In the middle cranial fossa microsurgery group, cochlear nerve and hearing can be preserved after tumor removal. Tinnitus handicap inventory and visual analogue scale scores were also evaluated in this group. The result of MCFA group is shown in Supplementary Fig. 3 (only online). MCFA group showed a similar rate of tinnitus improvement to the TLM group; however, there was no significant changes in mean tinnitus handicap inventory or visual analogue scale scores (p>0.05). They were excluded in the present study, because the number of MCFA group patients is too small and

Table 1. Patient Profiles of the Translabyrinthine Microsurgery (TLM) and Gamma Knife Radiosurgery (GKS) Groups

	TLM (n=27)	GKS (n=19)	p value
Age (yrs)	44.5±9.7	47.8±13.3	0.332
Gender (male : female)	7 : 20	4 : 15	0.703
Location of tinnitus (right : left : both)	12 : 14 : 1	5 : 12 : 2	0.322
Volume of tumor (cm^3)	5.05±8.68	4.37±6.91	0.764
Duration of tinnitus (month)	47.0±52.7	45.8±121.3	0.962
Duration of hearing loss (month)	48.7±46.8	70.5±135.4	0.441
Preoperative PTA*(dB) of lesion side	53.6±25.0	54.3±38.5	0.946
Preoperative SDS (%) of lesion side	34.5±29.3	25.2±39.1	0.405

PTA, pure tone audiometry; SDS, speech discrimination score.
*Average of hearing threshold at 500, 1000, 2000 and 3000 Hz.

this technique was applied only to patients who had relatively smaller size of the tumor and a better hearing compared to GKS group and TLM group. Future research in MCFA would help us prove the relationship between cochlear nerve continuity and tinnitus in the surgical treatment.

Previous reports on patients who underwent GKS showed that change in tinnitus occurred only in a few patients (4%),[15,16] whereas other studies showed reduced tinnitus in about 45% of patients treated with GKS.[17,18] In our study, patients who underwent GKS showed worsened tinnitus in 74%, based on tinnitus handicap inventory score.

Although various results of changes in tinnitus after microsurgery and GKS have been reported, our study showed better tinnitus control rate in the TLM than GKS group. Moller[19] suggested that the cause of tinnitus in vestibular schwannoma is peripheral nerve injury, whereas Lockwood, et al.[20] proposed that neural network malfunction due to the cerebral neural plasticity can be the cause of tinnitus. It is highly likely that a peripheral cause such as cochlea or cochlear nerve degeneration or firing has an important role in addition to a central cause in generating tinnitus in vestibular schwannoma patients. Therefore, vestibulocochlear nerve integrity is an important factor for tinnitus control after treatment; and cochlear nerve section may have benefit in postoperative tinnitus improvement. In some cases, secondary changes in the brainstem or post-brainstem central nervous system might act like phantom areas in generating tinnitus.[5,21-23] In these patients, vestibulocochlear nerve section

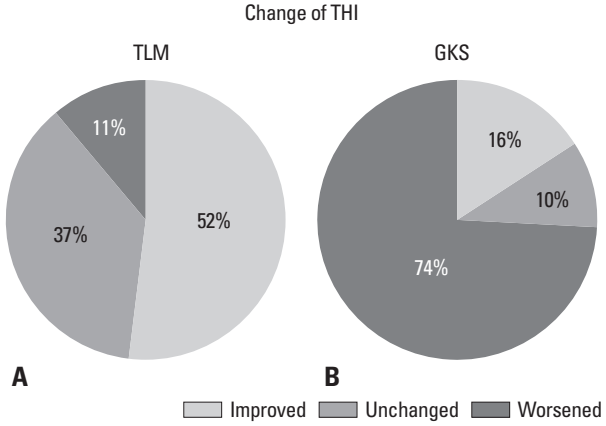


Fig. 2. Proportion of patients with change in tinnitus. The TLM group (A) had a much higher rate of tinnitus improvement compared to the GKS (B) group (p=0.016), which showed a significantly higher rate of tinnitus aggravation (p<0.001). THI, tinnitus handicap inventory; TLM, translabyrinthine microsurgery; GKS, gamma knife radiosurgery.

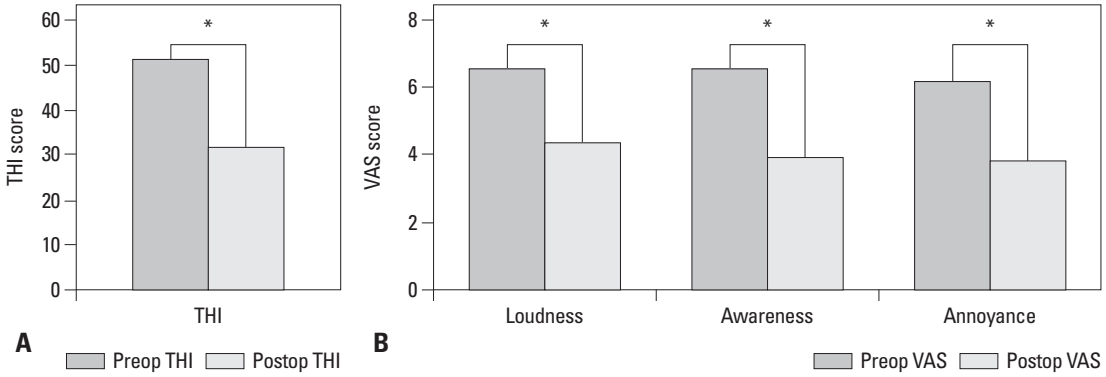


Fig. 3. Mean scores of tinnitus handicap inventory (THI) (A) and visual analogue scale (VAS) (B) in the TLM group. THI (*p=0.006) and VAS in loudness (*p=0.014), awareness (p=0.006), and annoyance (*p=0.006) were decreased significantly. TLM, translabyrinthine microsurgery.

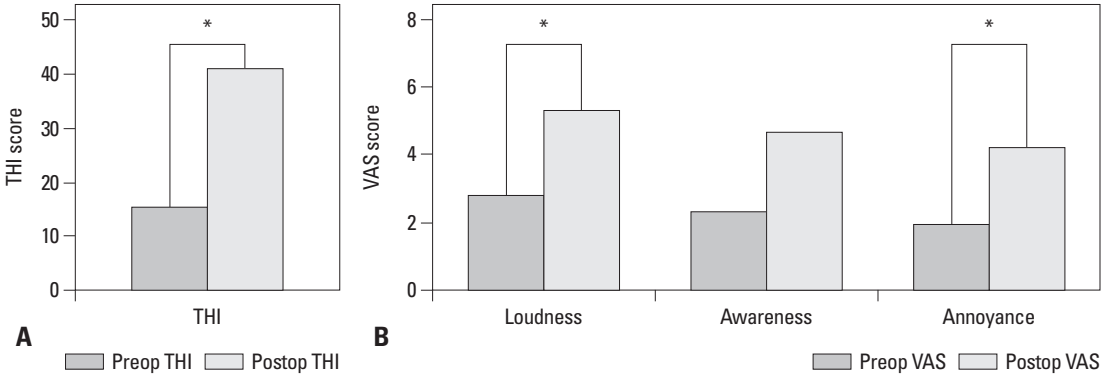


Fig. 4. Mean scores of THI (A) and VAS (B) in the GKS group. THI (*p<0.001) and VAS in loudness (*p=0.050) and annoyance (*p=0.034) were increased significantly. THI, tinnitus handicap inventory; VAS, visual analogue scale; GKS, gamma knife radiosurgery.

may be less effective or not helpful in reducing tinnitus after operation. After GKS, tumor swelling may occur prior to shrinkage, and damage to the peripheral organs can result from radiation exposure. Direct radiation-induced cochlear nerve toxicity is a causative factor for hearing loss and may result in worsening tinnitus.[9,24] Although controversial our results suggest that TLM with vestibulocochlear neurectomy may relieve or prevent tinnitus; even though GKS may induce damage to the cochlea and cochlear nerve by direct injury or swelling and cause worsening of tinnitus symptoms in a large proportion of patients.

There are many reports of tinnitus severity related to tumor size. Kohno, et al.[25] reported that the smaller tumour group show a significantly worse prognosis of tinnitus, and others claim that tinnitus is common when tumours are small or larger than 4.5 cm.[26] However, our study did not find any relationship between tumor volume and tinnitus handicap inventory scores or differences in pre- and postoperative tinnitus handicap inventory scores in both groups.

In studying hearing function, Kanzaki, et al.[27] found that tinnitus present in 78.6% of patients preoperatively increased to 89.3% postoperatively when hearing preservation was attempted. Kohno, et al.[25] found that the group with better preoperative hearing showed higher rate of worsening tinnitus. In our study, all patients in the TLM group sacrificed hearing, and there was no relationship between preoperative pure tone audiometry and pre- or postoperative tinnitus handicap inventory scores or change in tinnitus handicap inventory scores. In the GKS group, we also did not find any relationship between preoperative pure tone audiometry and pre- or postoperative tinnitus handicap inventory scores or change of tinnitus handicap inventory scores.

In cases where hearing preservation is not intended, cutting the vestibulocochlear nerve may help reduce the development of tinnitus in vestibular schwannoma treatment.

ACKNOWLEDGEMENTS

This study was supported by a grant from the National Research Foundation of Korea (Project number 2012R1A1A 2004323).

REFERENCES

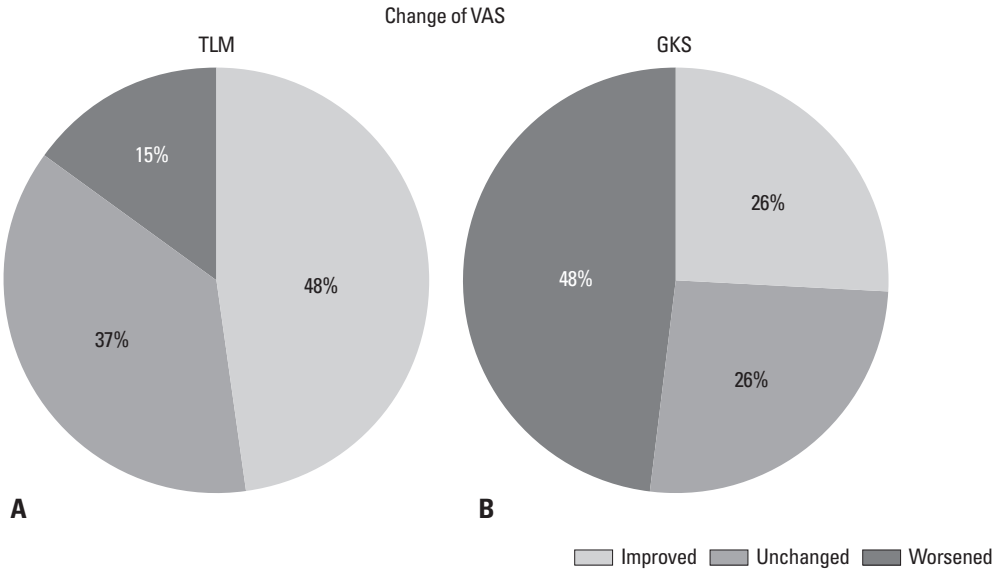
1. Propp JM, McCarthy BJ, Davis FG, Preston-Martin S. Descriptive epidemiology of vestibular schwannomas. Neuro Oncol 2006;8:1-11.
2. Moffat DA, Baguley DM, Beynon GJ, Da Cruz M. Clinical acumen and vestibular schwannoma. Am J Otol 1998;19:82-7.
3. Kentala E, Pyykkö I. Clinical picture of vestibular schwannoma. Auris Nasus Larynx 2001;28:15-22.
4. Haapaniemi J, Laurikainen E, Johansson R, Miettinen S, Varpula M. Cochleovestibular symptoms related to the site of vestibular schwannoma. Acta Otolaryngol Suppl 2000;543:14-6.
5. Møller AR. Pathophysiology of tinnitus. Ann Otol Rhinol Laryngol 1984;93(1 Pt 1):39-44.
6. Pulec JL, Hodell SF, Anthony PF. Tinnitus: diagnosis and treatment. Ann Otol Rhinol Laryngol 1978;87(6 Pt 1):821-33.
7. Shea JJ, Emmett JR, Orchik DJ, Mays K, Webb W. Medical treatment of tinnitus. Ann Otol Rhinol Laryngol 1981;90(6 Pt 1):601-9.
8. Hazell JW, Jastreboff PJ. Tinnitus. I: Auditory mechanisms: a model for tinnitus and hearing impairment. J Otolaryngol 1990;19:1-5.
9. Pollack AG, Marymont MH, Kalapurakal JA, Kepka A, Sathiaseelan V, Chandler JP. Acute neurological complications following gamma knife surgery for vestibular schwannoma. Case report. J Neurosurg 2005;103:546-51.
10. Kameda K, Shono T, Hashiguchi K, Yoshida F, Sasaki T. Effect of tumor removal on tinnitus in patients with vestibular schwannoma. J Neurosurg 2010;112:152-7.
11. Schaller BJ, Rasper J, Filis A, Buchfelder M. Difference in functional outcome of ipsilateral tinnitus after intraoperative occurrence of the trigemino-cardiac reflex in surgery for vestibular schwannomas. Acta Neurochir (Wien) 2008;150:157-60.
12. Haid C. Acoustic Tumor Surgery and Tinnitus. Int Tinnitus J 1998;4:155-8.
13. Harcourt J, Thomsen J, Tos M. Translabyrinthine vestibular schwannoma surgery: postoperative tinnitus and cochlear nerve integrity. Auris Nasus Larynx 1997;24:21-6.
14. Silverstein H, Haberkamp T, Smouha E. The state of tinnitus after inner ear surgery. Otolaryngol Head Neck Surg 1986;95:438-41.
15. Myrseth E, Møller P, Pedersen PH, Lund-Johansen M. Vestibular schwannoma: surgery or gamma knife radiosurgery? A prospective, nonrandomized study. Neurosurgery 2009;64:654-61.
16. Hempel JM, Hempel E, Wowra B, Schichor Ch, Muacevic A, Riederer A. Functional outcome after gamma knife treatment in vestibular schwannoma. Eur Arch Otorhinolaryngol 2006;263:714-8.
17. Bertalanffy A, Dietrich W, Aichholzer M, Brix R, Ertl A, Heimberger K, et al. Gamma knife radiosurgery of acoustic neurinomas. Acta Neurochir (Wien) 2001;143:689-95.
18. Niranjan A, Lunsford LD, Flickinger JC, Maitz A, Kondziolka D. Dose reduction improves hearing preservation rates after intracanalicular acoustic tumor radiosurgery. Neurosurgery 1999;45:753-62.
19. Moller AR. Similarities between severe tinnitus and chronic pain. J Am Acad Audiol 2000;11:115-24.
20. Lockwood AH, Salvi RJ, Coad ML, Towsley ML, Wack DS, Murphy BW. The functional neuroanatomy of tinnitus: evidence for limbic system links and neural plasticity. Neurology 1998;50:114-20.
21. Berliner KI, Shelton C, Hitselberger WE, Luxford WM. Acoustic tumors: effect of surgical removal on tinnitus. Am J Otol 1992;13:13-7.
22. House JW, Brackmann DE. Tinnitus: surgical treatment. Ciba Found Symp 1981;85:204-16.
23. Jastreboff PJ, Hazell JW. A neurophysiological approach to tinnitus: clinical implications. Br J Audiol 1993;27:7-17.
24. Linskey ME, Johnstone PA, O'Leary M, Goetsch S. Radiation ex-

posure of normal temporal bone structures during stereotactically guided gamma knife surgery for vestibular schwannomas. J Neurosurg 2003;98:800-6.
25. Kohno M, Shinogami M, Yoneyama H, Nagata O, Sora S, Sato H. Prognosis of Tinnitus After Acoustic Neuroma Surgery-Surgical Management of Postoperative Tinnitus. World Neurosurg 2012.
26. Baguley DM, Humphriss RL, Axon PR, Moffat DA. The clinical characteristics of tinnitus in patients with vestibular schwannoma. Skull Base 2006;16:49-58.
27. Kanzaki J, Satoh A, Kunihiro T. Does hearing preservation surgery for acoustic neuromas affect tinnitus? Skull Base Surg 1999; 9:169-76.

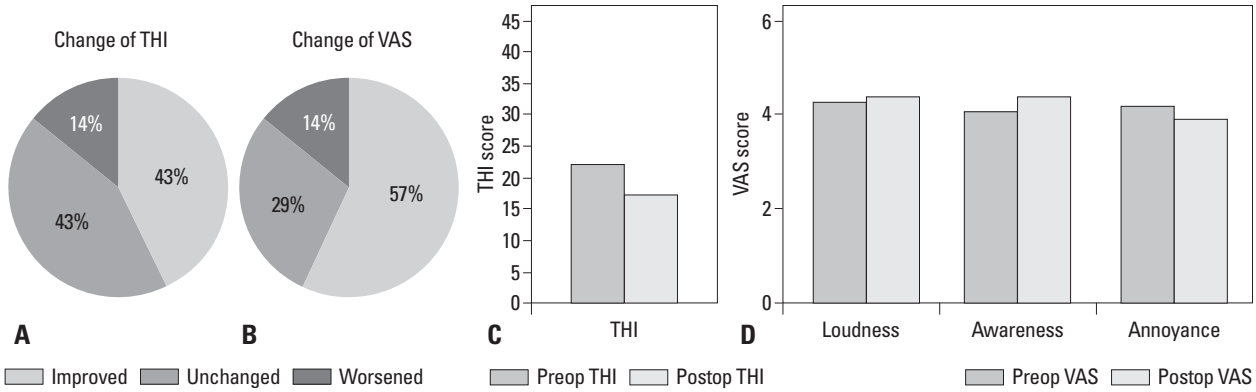
INSTRUCTIONS: The purpose of this questionnaire is to identify difficulties that you may be experiencing because of your tinnitus. Please answer every question. Please do not skip

1. Because of your tinnitus, is it difficult for you to concentrate?	Yes	Sometimes	No
2. Does the loudness of your tinnitus make it difficult for you to hear people?	Yes	Sometimes	No
3. Does your tinnitus make you angry?	Yes	Sometimes	No
4. Does your tinnitus make you fell confused?	Yes	Sometimes	No
5. Beacuse of your tinnitus, do you feel desperate?	Yes	Sometimes	No
6. Do you complain a great deal about your tinnitus?	Yes	Sometimes	No
7. Because of your tinnitus, do you have trouble falling to sleep at night?	Yes	Sometimes	No
8. Do you feel as tyough you cannot escape your tinnitus?	Yes	Sometimes	No
9. Does your tinnitus interfere with your ability to enjoy your social activities (such as going out to dinner, to the movies)?	Yes	Sometimes	No
10. Because of your tinnitus, do you feel frustrated?	Yes	Sometimes	No
11. Because of your tinnitus, do you feel that you have a terrible disease?	Yes	Sometimes	No
12. Does your tinnitus make it difficult for you enjoy life?	Yes	Sometimes	No
13. Does your tinnitus interfere with your job or household responsibilities?	Yes	Sometimes	No
14. Because of your tinnitus do you find that you are often irritable?	Yes	Sometimes	No
15. Because of your tinnitus, is it difficult for you to read?	Yes	Sometimes	No
16. Does your tinnitus make you upset?	Yes	Sometimes	No
17. Do you feel that your tinnitus problem has placed stress on your relationships with members of your family and friends?	Yes	Sometimes	No
18. Do you find it difficult to focus your attention away from your tinnitus and on other things?	Yes	Sometimes	No
19. Do you feel that you have no control over your tinnitus?	Yes	Sometimes	No
20. Because of your tinnitus, do you often fell tired?	Yes	Sometimes	No
21. Because of your tinnitus, do you feel depressed?	Yes	Sometimes	No
22. Does your tinnitus make you feel anxious?	Yes	Sometimes	No
23. Do you feel that you can no longer cope with your tinnitus?	Yes	Sometimes	No
24. Does your tinnitus get worse when you are under stress?	Yes	Sometimes	No
25. Does your tinnitus make you feel insecure?	Yes	Sometimes	No

Supplementary Fig. 1. Neumann's Tinnitus Handicap Inventory.



Supplementary Fig. 2. Proportion of patients with change in tinnitus according to visual analogue scale (VAS). The translabyrinthine microsurgery (TLM) (A) showed lower rate of tinnitus aggravation comto group. The gamma knife radiosurgery (GKS) group (p=0.022) (B).



Supplementary Fig. 3. Change of tinnitus in middle cranial fossa microsurgery group. Tinnitus handicap inventory (THI) and visual analogue scale (VAS) showed similar rate of tinnitus improvement to the translabyrinthine microsurgery group (A and B). But, mean THI and VAS showed no significant changes (C and D).