Auditory Electrical Tinnitus Suppression in Patients With and Without Implants

Ahmad Daneshi,[1] Saeed Mahmoudian,[2] M. Farhadi,[2] S. Hasanzadeh,[3] and B. Ghalebaghi[2]

[1] Department of Otolaryngology, Rasoule Akram Hospital; [2] Department and Research Center of Ear, Nose, Throat, and Head and Neck Surgery; and [3] Iran Cochlear Implant Center, Iran University of Medical Sciences, Tehran, Iran

Abstract: The aim of this study was to evaluate the effectiveness of electrical tinnitus suppression in two groups of chronic severe tinnitus sufferers. Through standard tinnitus questionnaires, we compared the effectiveness of extratympanic and intratympanic auditory electrical stimulation (AES) by cochlear implants (CI) for the suppression or abolition of the perception of tinnitus and the decrease of its associated complaints. We made otolaryngological and comprehensive audiological assessment and also tinnitus measurement in each group of patients before and after AES and 50 days later. We investigated the dimensions of psychological complaints due to chronic and disabling tinnitus by means of the tinnitus questionnaire (TQ).

The control examination during at least seven sessions (50 days) after AES in the group of patients without implants showed improvement in 20 of 32 patients (62.5%); 12 (37.5%) did not notice any change. In the comparative group of patients with implants, improvement occurred in 16 of 20 patients (75%); during the switch-on of the speech processor, these patients reported significant attenuation or complete suppression of their tinnitus. Complete suppression of the tinnitus after CI was observed for 11 patients (55%), and 5 patients (25%) demonstrated significant attenuation of tinnitus. Nonsuppression of tinnitus was observed for only 4 patients (25%). None of our patients was affected by an increment in the tinnitus owing to CI. The differences of means of scores in the standard TQ were significant in both groups of patients. A comparison of TQ score differences between patients with and without implants showed no significance. We concluded that AES is a useful and effective therapeutic intervention in patients with tinnitus. Extratympanic AES reduces the effects of the tinnitus but presents limitations, mainly owing to the short duration of the electrical residual inhibition of the tinnitus. CI is shown to be more efficient for the treatment of tinnitus, mainly because the electrical stimulation affects a wider area of the cochlea and is presented for longer sessions. Therefore, patients affected by incapacitating tinnitus should be considered for continuous use of electrical stimulation.

Key Words: auditory electrical stimulation; cochlear implantation; tinnitus suppression

Tinnitus is the consciousness of sound that arises in the head without an obvious voluntary origin [1,2]. This symptom is a widespread problem that can cause considerable disability or handicap in tinnitus patients. Davis [2] reported that tinnitus is a major factor associated with hearing impairment. He found that some 10% of all adults report prolonged spontaneous tinnitus and that approximately 5% of those have moderately or severely annoying tinnitus. He also reported that 2–4% of tinnitus patients have been referred to a hospital for their tinnitus. Coles [3] found that 1–2 adults in 100 report tinnitus that has had a severe effect on their quality of life. Psychiatric studies have indicated that tinnitus may also increase the risk for developing a subsequent mental disorder

Reprint requests: Saeed Mahmoudian, MSc, Department and Research Center of Ear, Nose, Throat, and Head and Neck Surgery, Iran University of Medical Sciences, Sattarkhan Avenue, Niayesh Street, Hazrate-Rasoul Medical and Educational Complex, Tehran, Iran. Phone: +9821-6504294 (office), +9821-7425174 (home); Fax: +9821-6525329; E-mail: saeedmah@iums.ac.ir; Mahmoudian@ent-hns.org

[4,5]. Self-report and clinical assessments are much in agreement. The first systematic study of self-report tinnitus appears to be that of Tyler and Baker [6].

Standard questionnaire studies have been performed using various aspects of tinnitus complaint behavior. As a first approach toward the specific assessment of tinnitus-related disturbances, Hallam et al. [7] developed a self-rating scale to cover the most frequent complaints reported by tinnitus patients attending a neuro-otological outpatient clinic. Hiller and Goebel [8] and Hiller et al. [9] obtained similar results. The main role of such questionnaires lies in assessing the effectiveness of therapy using before-and-after presentations rather than in a global evaluation of patients prior to therapy. Various modes of treatment to suppress tinnitus have been attempted with different workers.

Auditory electrical stimulation (AES) is one treatment that has been explored for tinnitus suppression and has shown some benefit. Historically, Feldmann reported that Grapergiesser was one of the first investigators to work on tinnitus suppression by transcutaneous stimulation with Volta's platinum zinc cell (as cited in Watanabe et al. [10]). Since then, numerous workers have performed electrical stimulation with electrodes placed at various sites and using different waveforms of electrical stimuli.

Electrical stimulation for tinnitus suppression was investigated by many authors who reported its effectiveness: 22% by Graham and Hazell (1987) (as cited in Balkany et al. [11]); 57.4% by Matsushima [12]; 67.6% by Okusa et al. [13]; and, finally, 87% by Portman (1979) (as cited in Balkany et al. [11]). The purpose of our study was to evaluate the effectiveness of electrical tinnitus suppression in two sample groups of chronic severe tinnitus sufferers. We compared the effectiveness of AES and the role of cochlear implant (CI) for the suppression or abolition of the perception of tinnitus, and the degree of disability owing to tinnitus was evaluated using standard tinnitus questionnaires as well as relative standard tinnitus questionnaires (TQs).

SUBJECTS AND METHODS

Subjects

In the period between 1999 and 2002, we treated 52 adult patients (two groups) suffering from moderate to severe or disabling tinnitus. One group consisted of 32 patients without implants (20 male, 12 female; mean age, 42.19 years; age range, 21–67 years) affected by tinnitus and moderate to severe hearing loss with a nucleus promontory stimulator. A second group included 20 patients with implants (12 male, 8 female; mean age, 28.85 years; age range, 14–56 years) affected by incapacitating tinnitus and profound hearing loss on both sides (11 implanted with Nucleous-22 and 9 with Combi 40+ devices). All patients who were implanted were postlingually deaf.

The members of both groups had been unsuccessfully treated by many medical methods and gave their written consent to participate in this study. It was approved by the Iranian Cochlear Implant Center committee and a committee of the department and research center of otolaryngology and head and neck surgery.

In the group of patients treated with extratympanic AES (EAES), the location of tinnitus was the right ear in 4 patients and the left in 13 patients; it was bilateral in 13 patients and occurred in the middle of the head in 2 patients. In the group of patients treated by CI, the location of tinnitus was the right ear in 1 patient and the left in 4; it was bilateral in 10 patients and occurred in the middle of the head in 5 patients.

Procedure

Pre- and postelectrical stimulation evaluation consisted of a comprehensive audiological examination; history taking; medical examination; temporal bone x-ray; electrophysiological tests (e.g., auditory brainstem response and electrocochleography); tinnitus psychophysical measurement (pitch match and loudness matching, minimal masking level, and residual inhibition and annoyance scaling); pure-tone audiometry; and tympanometry.

The patients without implants received EAES with a nucleus promontory stimulation system, which was used for the evaluation of CI candidates. They received bipolar stimulation under 600-Hz burst currents (square waves) presented for a duration of 0.5 seconds in seven sessions of 30 minutes. We measured the tinnitus severity scale (TSS) together with the loudness and pitch of the tinnitus before and after AES.

The patients with implants were asked about the tinnitus affecting them (location, quality, tinnitus awareness, kind of noise perceived, how often it appeared, and the like) before the implantation and after the first switch-on of the processor.

Pitch Match and Loudness Balance Test

We estimated tinnitus identification parameters objectively as follows [10]. For the tinnitus pitch-match test, we used a two-alternative forced-choice method. We gave different pairs of pitch sounds from a clinical audiometer (Madsen OB822) at 11 frequencies (from 125 Hz through 12 kHz); we then decreased or increased the pitch (which was not similar to tinnitus), after which subjects were asked to identify which one best matched

the pitch of their tinnitus. Pitch-match test was typically multiples of 1 kHz. Finally, we administered an octave confusion test for a final pitch-match test. Before each tone pair was presented, they were adjusted to a loudness level equivalent to that of the tinnitus.

Tinnitus loudness match was obtained at each of the test tones used in the pitch-matching procedure. Subsequently, with the auditory threshold level (*a*) at that frequency, the sound was increased in 1-dB steps until a patient reported that the external tone equaled the loudness of the tinnitus. The sound level matching that of the tinnitus (*b*) and the sound level a little louder than that of the tinnitus (*c*) were obtained by an audiometer (loudness balance test). We used the mean level of loudness between points (*b*) and (*c*) as the representative loudness of tinnitus. The formula of the loudness (expressed as decibels of sensation level [dB SL]) is as follows:

$$\text{Loudness of tinnitus} = [(b + c)/2 - a] \text{ dB SL}$$

The criteria of objective methods for evaluating tinnitus after AES using tinnitus identification parameters were such that the change seen as a diminishing or worsening of tinnitus loudness match or changes in the pitch of tinnitus occurred when reduced or increased by at least 1,000 Hz and loudness was reduced or increased by at least 2 dB SL.

In the implanted group, subjects were asked to rate the loudness of their tinnitus on a 10-point visual analog scale and a TSS for a total of four sessions to determine the stability of their tinnitus without treatment. Also, to determine the quality and pitch of tinnitus, they were asked about the kind of noise they perceived prior, during, and after the switch-on of the processor. The minimum level of stimulated signal that registers as inaudible in tinnitus was recorded and termed the *minimum masking level*; also, the duration of tinnitus loudness reduction after AES was termed the *electrical residual inhibition*.

Tinnitus Questionnaire

We administered the Persian version of the TQ as a measure of dimensions of associated tinnitus complaints. (The instrument had been translated into Persian by two independent and experienced clinicians, both fluent in English and Persian.) The questionnaire then was retranslated and carefully compared to achieve maximum congruence. Original and translated versions were additionally reviewed by two other bilingual and bicultural colleagues on our staff.

The TQ consists of 52 items that assess the subjective psychological effects of AES as described by patients. These factors included emotional distress, cognitive distress, intrusiveness, auditory perceptual difficulties, sleep disturbances, and somatic complaints. For each factor, respondents were asked to indicate their agreement by circling one of the three response alternatives: true (scored as 2), partly true (scored as 1), and not true (scored as 0) [7]. The Cronbach alpha is high (0.91–0.95), indicating a high degree of internal consistency, and the high test-retest correlation (0.91–0.94) indicates very good stability over time [14]. Improvement or worsening of condition was determined by patients' declaring a change in tinnitus of at least 40%.

Extratympanic and Intratympanic AES by Cochlear Implant

AES was performed by inserting an active surface tympanic membrane electrode through the external ear inside the posterior inferior tympanic membrane and locating a silver surface electrode on the forehead, delivered by a stimulation system (nucleus promontory stimulator) that was used for evaluating CI candidates. Next, we put a saline solution in the ear canal and measured four current levels: first, the smallest current level (including sound sensation in patients); second, the tinnitus suppression level; and finally, the most comfortable level and the uncomfortable current level at which patients felt pain. Bipolar 50-Hz burst currents (square waves) were presented for a duration of 0.5 second. We then stimulated the tinnitus ear at current levels, which were at the maximum comfort level. The stimulus duration of the AES was 20 minutes for seven sessions on a twice-weekly basis. The scope of electrical impulse differed with individual patients and depended on tinnitus parameters and patient sensation.

The AES included levels ranging from 60 to 500 μAmp. Depending on individual tolerance and frequency, it ranged from 50 to less than 600 Hz. We performed a statistical analysis of all relevant data with the paired *t*-test.

After AES (first, mid-, and final session), we estimated the therapeutic effects by patients' subjective reports of changes of tinnitus by TQs and the pitch-match and loudness balance tests. Changes were classified into three groups: Tinnitus became inaudible or reduced (complete or partial residual inhibition); tinnitus was not changed (nonresidual inhibition); or tinnitus became worse than before AES or before CI (increment of the tinnitus). In all patients, we performed the loudness match test, and the subjective changes on TQ items paralleled the changes in the loudness match test.

In the patients with implants, the criteria of subjective methods also were exactly the same criteria as those for patients without implants (the AES group): before the implantation, after the first switch-on of the

processor, and some 2 months later. All patients with implants were postlingually deaf.

RESULTS

The duration of tinnitus in patients treated with EAES ranged from 6 months to 32 years (mean, 90.19 ± 92.81 months). Tinnitus duration in patients treated with CI ranged from 12 months to 28 years (mean, 117.60 ± 69.92 months). We estimated the therapeutic effects by patients' subjective reports of changes in the tinnitus. The tinnitus was present always or almost always for 15 (75%) and often for 5 (25%) patients with implants. The severity of tinnitus before the CI is shown in Figure 1.

Although the characteristics of tinnitus varied considerably across subjects, all subjects considered their tinnitus to be "intense," "relatively intense," or "moderate," affecting their lives on a daily basis. In rating average prestimulation tinnitus loudness, more than one-half (65%) rated their tinnitus as greater than 7 on a 10-point visual analog scale. The mean baseline loudness rating was 7.2/10. Most subjects (93.4%) had experienced tinnitus for 2 years or longer.

Tinnitus Suppression

After CI, 16 of the studied patients reported a significant elimination or substantial reduction of the incidence of tinnitus. Complete suppression of the tinnitus after CI was observed in 11 patients (55%), and 5 patients (25%) indicated a significant attenuation of tinnitus. Nonsuppression of the tinnitus was observed for only 4 patients (20%). None of our patients was affected by an increment in the tinnitus due to CI.

Twenty of 32 patients (62.5%) in the nonimplanted group indicated that their tinnitus was suppressed after AES. The treatment had no effect on 12 patients (32.5%). Tinnitus did not become worse in any of our tinnitus sufferers. The duration of suppression after stimulus is shown in Table 1. All 16 patients with implants experienced significant attenuation or complete

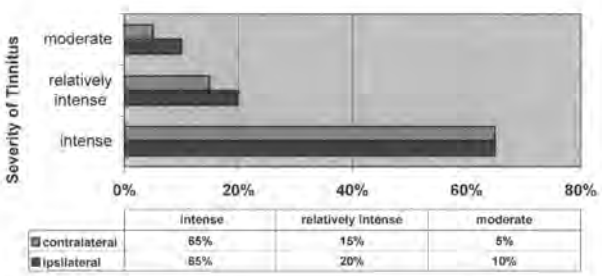

Figure 1. Incidence of tinnitus severity before cochlear implant.

Table 1. Frequency Distribution of Electrical Residual Inhibition in Patients With and Without Implants After Auditory Electrical Suppression

Type of Electrical Residual Inhibition	No. of Patients Without Implants (%)	No. of Patients With Implants (%)
Complete electrical residual inhibition	5 (15.6)	11 (55)
Partial electrical residual inhibition	15 (46.9)	5 (25)
Nonelectrical residual inhibition	12 (37.5)	4 (20)
Total	32 (100)	20 (100)

suppression of their tinnitus during the switch-on of the speech processor. Tinnitus was not aggravated in any patient (in either group).

Pitch and Loudness of Tinnitus

In the patients without implants, the mean difference in the tinnitus pitch from 6,153.5 Hz (SD = 2,280.5) to 6,618.7 Hz (SD = 2,330.2) was not significant in the suppression group nor from 6,820 Hz (SD = 2,852.5) to 5,386 Hz (SD = 3,693) in the nonsuppression group ($p > .05$). In the suppression group, the decrease in the mean of tinnitus loudness from 7.12 dB SL (SD = 2.86) to 4.83 dB SL (SD = 2.36) was significant (paired t-test, $p < .001$), but in the nonsuppression group, the mean difference in the loudness from 6.95 dB SL (SD = 2.02) to 7.17 dB SL (SD = 1.99) was not significant.

In the patient group with implants, we perceived no significant differences in kind of noise, such as tinnitus before and after CI ($p > .05$). The difference of the means in the TSS from 40.36 (SD = 10.59) to 30.18 (SD = 8.63) was significant in patients with CI ($p < .001$).

Changes in the Tinnitus Questionnaire

We analyzed all factors of the TQ before and after intervention by EAES in all cases. In patients without implants, the decrease in the mean scores of their emotional distress factor from 52.43 (SD = 18.48) to 39.86 (SD = 22.69) was significant (paired t-test, $p = .001$) and, in the CI patients, the mean differences from 52.27 (SD = 20.75) to 35.57 (SD = 19.06) was similarly significant ($p = .001$). Also, in both groups, the mean differences in the scores of the TQ—including cognitive distress, emotional distress, emotional-cognitive distress, intrusiveness, auditory perceptual difficulties, sleep disturbances, and somatic disturbances before and after AES—were significant (for all, $p < .05$). Changes in the scores of the TQ in both groups are shown in Table 2.

Table 2. Differences in Tinnitus Questionnaire Mean Scores Before and After Auditory Electrical Suppression in Patients With and Without Implants

	Patients Without Implants			Patients With Implants		
Psychological Complaint	**Before (Mean ± SD)**	**After (Mean ± SD)**	***p* Value**	**Before (Mean ± SD)**	**After (Mean ± SD)**	***p* Value**
Emotional distress	52.43 ± 18.48	39.86 ± 22.69	.001	52.27 ± 20.75	35.57 ± 19.06	.001
Cognitive distress	55.07 ± 20.36	44.19 ± 18.43	.001	58.75 ± 18.27	46.46 ± 19.77	.007
Emotional-cognitive distress	52.83 ± 18.70	41.97 ± 19.24	.005	58.58 ± 17.86	44.13 ± 18.53	.003
Intrusiveness	56.47 ± 21.79	44.73 ± 25.05	.000	60.05 ± 17.62	45.35 ± 21.32	.004
Auditory perceptual difficulties	52.01 ± 25.99	37.62 ± 27.24	.004	49.99 ± 29.56	31.08 ± 22.81	.004
Sleep disturbances	42.92 ± 36.32	32.46 ± 32.34	.01	47.60 ± 29.90	36.90 ± 26.43	.004
Somatic disturbances	38.58 ± 32.36	27.73 ± 30.97	.02	41.11 ± 29.46	26.60 ± 29.48	.02
Total complaints	50.66 ± 19.34	39.03 ± 20.35	.000	52.84 ± 14.82	38.45 ± 13.99	.001

SD = standard deviation.

For the comparison of the prognosis of electrical stimulation treatment in patients with and without implants, we subtracted the first TQ scores from the second TQ scores (i.e., scores after 50 days) and compared the result between two groups with a *t*-test. Interestingly, we observed no significant difference ($p = .49$; Table 3). The comparison between global TQ score means across two groups is shown in Figure 2.

DISCUSSION

Management of patients with tinnitus is an extremely perplexing problem. Also, the treatment of tinnitus is still an open challenge, there being no single way to resolve it to date. Tinnitus suppression is well-known to occur during and after the treatment period with the use of AES [15]. Also, researchers have found that in a number of CI users, tinnitus was significantly reduced or disappeared when their implants were switched on.

Table 3. Comparison of Tinnitus Questionnaire Mean Score Differences Between Patients With and Without Implants

Psychological Complaint	**Patients Without Implants (Mean ± SD)**	**Patients With Implants (Mean ± SD)**	***p* Value**
Emotional distress	−13.06 ± 21.28	−20.69 ± 18.05	.23
Cognitive distress	−10.87 ± 16.93	−12.26 ± 15.23	.78
Emotional-cognitive distress	−10.86 ± 15.81	−14.45 ± 15.66	.47
Intrusiveness	−11.74 ± 18.22	−14.70 ± 16.75	.59
Auditory perceptual difficulties	−14.38 ± 25.86	−18.91 ± 12.56	.55
Sleep disturbances	−12.45 ± 25.62	−10.69 ± 12.05	.80
Somatic disturbances	−10.80 ± 24.53	−14.50 ± 22.29	.62
Total complaints	−11.57 ± 13.41	−14.39 ± 12.57	.49

House and Brackmann [16] evaluated 29 CI patients who also were experiencing tinnitus. House [17], who initiated the CI procedure, previously observed that electrical stimulation within the cochlea produced a suppression of tinnitus in some patients. Electrical stimulation from the CI produced total suppression of tinnitus in 8 patients (28%) and partial suppression in 15 patients (52%), for a total of 80% of their patients experiencing some degree of tinnitus relief. No patient's tinnitus was worsened by electrical stimulation.

The CI uses alternating current rather than direct current. In our study, the percentages of patients showing improvement in the CI group (80%) and in the EAES group (62.5%) are comparable with those found previously; the percentages were 67% and 59%, respectively, in Ruiz-Rico et al. [18] and 54% in Collet et al. [19] and in House [17]. We had observed a significant decrease in the incidence of tinnitus both in patients treated with CI and in those treated with extratympanic AES. We used the EAES technique only in patients who had severe tinnitus and for whom other treatments were unsuccessful. The effectiveness of electrical stimulation depends on the characteristics of the electrical stimulus and on the anatomical area of stimulation [20].

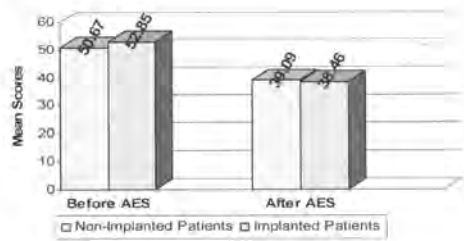

Figure 2. Comparison of global tinnitus questionnaire mean scores for patients with and without implants. (*AES* = auditory electrical suppression.)

In our opinion, beside the characteristics of electrical stimulation, a significant factor is the continuous use of AES. The method was explained and accepted by all our patients. In a clinical context, we used AES to treat people who were experiencing significant levels of distress, to specify precisely the nature of their difficulties and to assess the outcome of specific therapeutic intervention. We used extratympanic and intratypanic AES with a visual analog scale, tinnitus identification parameters, and a standard TQ.

The TQ, developed by Hallam et al. [7], represents a promising step toward improving the description and measurement of psychological complaints associated with chronic tinnitus. The TQ seems to be the most comprehensive assessment of tinnitus-related complaints [13,14]. Further, the TQ is the only instrument providing a very broad description, with six scales derived from both factor analysis and clinical evidence [14]. After seven sessions (50 days) of treatment by EAES, we found a significant difference in all dimensions of the TQ before and after electrical stimulation in patients both with and without implants ($p < .05$).

Continuous use of electrical stimulation by CI or external electrical stimulus seems to produce a progressive inhibition of the tinnitus in patients with distressing tinnitus. Therefore, the mechanism involved in the tinnitus inhibition is not only tinnitus masking. Continuous electrical stimulation reduces the spontaneous firing of the ipsilateral and contralateral cochlear nerves, probably owing to the reactivation of the efferent system. Also, the continuous use of electrical stimulation produces a cumulative reduction of the incidence of tinnitus in patients treated with CI, and EAES causes improvement of the residual inhibition in tinnitus patients.

Although study comparisons are confounded by differences in success criteria, subject sampling, and methodology, acute tinnitus suppression has been reported in up to 67% of subjects [21]. The suppression of tinnitus after AES has been widely reported [10–13,15,16,21,22]. This stimulus might cause the reduction of the effects of tinnitus. Many factors could be involved in this reduction. The effects on the cochlear nerve play an important role in the suppression of tinnitus by electrical stimulation, synchronizing discharges of the auditory nerve fibers, and inhibition of the abnormal activity of the cochlear nerve. Another factor may be the revival of the neural coding pattern of auditory information in the neural pathways and normalization of silent coding patterns in the auditory cortex; the mechanisms involved in the improvement of tinnitus effects are probably related to created neural plasticity during that period. Also related is reactivation of the efferent system. The mechanism of beneficial effect by electrical stimulation on tinnitus suppression can be due to increased microcirculation in part of the auditory pathways as a reflex effect [23].

Although no specific waveform proved to be selectively effective, the frequency of stimulation was important. In general, frequencies ranging up to 600 Hz tended to be more effective than were higher stimuli in creating suppression in the highest proportion of patients.

We can conclude that AES is a useful and effective therapeutic intervention in patients with tinnitus. AES appears to alleviate tinnitus by altering the acoustic pattern of the tinnitus to one that is less annoying or to eradicate the tinnitus completely. The permanence of the improvement varies greatly. Also, according to our experience, we offer use of this intervention in patients with such compliance early in their workup, because early intervention seems to help positive plasticity of neurons and to provide better results in tinnitus rehabilitation. Therefore, patients affected by incapacitating tinnitus should be considered for continuous use of electrical stimulation.

Our study measured certain therapeutic effects of AES for tinnitus relief in patients with persistent tinnitus, but our results may have been due to treatment or to other nonspecific effects. The adverse effects of AES are minimal. A significant number of patients reported improvement in hearing sensitivity and also a considerable degree of relaxation during and after AES, but this could not be verified by objective evaluation. Possibly, insignificant clinical changes of the auditory threshold occurred, as our measurements were not sufficiently sensitive. We would stress that our results should be viewed with caution, given the small size of our patient sample, and we invite further study to render precise indications for AES (intratympanic or extratympanic) that are as meaningful as possible.

REFERENCES

1. McFadden D. Tinnitus: Facts, Theories, and Treatments. *Report of Working Group 89, Committee on Hearing, Biomechanics, National Research Council*. Washington DC: National Academy Press, 1982.
2. Davis A. Epidemiology of Tinnitus and Its Clinical Relevance. In *The Sixteenth European Instructional Course, "Tinnitus and Its Management."* London: Nottingham School of Audiology, April 1996:13–18.
3. Coles RRA. Epidemiology of tinnitus: 1. Prevalence. *J Laryngol Otol* 9(suppl):7–15, 1985.
4. Simpson RB, Nedzelski JM, Barber HO, Thomas MR. Psychiatric diagnosis in patients with psychogenic dizziness or severe tinnitus. *J Otolaryngol* 17:325–330, 1988.
5. Harrop-Griffiths J, Kayton W, Dobie R, et al. Chronic tinnitus: Association with psychiatric disorders. *J Psychosom Res* 37:613–621, 1987.

6. Tyler RS, Baker LJ. Difficulties experienced by tinnitus sufferers. *J Speech Hear Dis* 48:150–154, 1983.
7. Hallam RS, Jakes SC, Hinchcliffe R. Cognitive variables in tinnitus annoyance. *Br J Clin Psychol* 27:213–222, 1988.
8. Hiller W, Goebel G. A psychometric study of complaints in chronic tinnitus. *J Psychosom Res* 36(4):337–348, 1992.
9. Hiller W, Goebel G, Rief W. Reliability of self-rated tinnitus distress and association with psychological symptom patterns. *Br J Clin Psychol* 33:231–239, 1994.
10. Watanabe KI, Okawara D, Baba S, Yagi T. Electrocochleographic analysis of the suppression tinnitus by electrical promontory stimulation. *Audiology* 36:147–154, 1997.
11. Balkany T, Banti H. Direct electrical stimulation of the inner ear for the relief of tinnitus. *Am J Otol* 8:207–212, 1987.
12. Matsushima JI, Fujimura H, Sakai N, et al. A study of electrical promontory stimulation in tinnitus patients. *Auris Nasus Larynx* 21:17–24, 1994.
13. Okusa M, Shirashi T, Kubo T, Matsumaga T. Tinnitus suppression by electrical promontory stimulation in sensorineural deaf patients. *Acta Otolaryngol (Stockh)* 501:54–58, 1993.
14. Henry JL, Wilson PH. Psychometric Assessment of Tinnitus Problems. In *The Psychological Management of Chronic Tinnitus: A Cognitive-Behavioural Approach*. New York: Allyn and Bacon, 2001:38–39.
15. Hazell JW, Jasterboff PJ, Meerton LE, Conway MJ. Electrical tinnitus suppression: Frequency dependence of effects. *Audiology* 32:68–77, 1993.
16. House JW, Brackmann DE. Tinnitus: Surgical Treatment. In D Evered, G Lawrenson (eds), *Tinnitus: CIBA Foundation Symposium 85*. London: Pitman Books, 1981:204–216.
17. House WF. Cochlear implants. *Ann Otol Rhinol Laryngol* 185(suppl 27):1–93, 1976.
18. Ruiz-Rico R, Sainz M, de la Torre RC. Reduction of the Incidence of Tinnitus in Patients Treated with Cochlear Implants. *Sixth European Symposium on Paediatric Cochlear Implantation*, 2001.
19. Collet L, Moussu MF, Dubreuil C, et al. Psychological factors affecting outcome of treatment after transcutaneous electrotherapy for persistent tinnitus. *Arch Otorhinolaryngol* 244:20–22, 1987.
20. Engelberg M, Bauer W. Transcutaneous electrical stimulation for tinnitus. *Laryngoscope* 95:1167–1173, 1985.
21. Hazell JW, Meerton LJ, Conway MJ. Electrical tinnitus suppression (ETS) with a single channel cochlear implant. *J Laryngol Otol* 18:39–44, 1989.
22. Graham JM. Electrical stimulation of the human cochlea using a transtympanic electrode. *Br J Audiol* 11:59–62, 1977.
23. Konopka W, Zalewski P, Olszewaski J, et al. tinnitus suppression by electrical promontory stimulation (EPS) in patients with sensorineural hearing loss. *Auris Nasus Larynx* 28(1):35–40, 2001.