REVIEW ARTICLE

Chronic Tinnitus: an Interdisciplinary Challenge

Peter M. Kreuzer, Veronika Vielsmeier, Berthold Langguth

SUMMARY

Background: Tinnitus is defined as the perception of sound in the absence of a corresponding external acoustic stimulus. It is a common problem that markedly impairs the quality of life of about 1% of the general population.

Methods: We selectively reviewed the pertinent literature to provide an overview of the current treatment options for chronic tinnitus.

Results: Cognitive behavioral therapy is effective and is the best studied of all currently available treatments. All patients should have a therapeutic interview for counseling. Auditory stimulation can also lessen tinnitus: It is used in tinnitus maskers and hearing aids, as well as in tinnitus retraining therapy. An improved understanding of the neural mechanisms of tinnitus has led to the development of innovative techniques of neuromodulation and neurostimulation, but these are still experimental. Drugs are indicated only for the treatment of tinnitus-associated symptoms such as depression, sleep disturbances, and anxiety.

Conclusion: There are many ways to treat chronic tinnitus, and new treatments are now being developed. As tinnitus has many causes and can be associated with many different comorbid disturbances, multidisciplinary diagnostic evaluation and treatment are important. For many tinnitus patients, long-term therapeutic success depends on the maintenance of a therapeutic relationship with the treating physician, so that the physician and the patient can work together to give careful consideration to each newly proposed diagnostic test or treatment step.

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The term “tinnitus” (from the Latin *tinnire*, to ring) describes a disorder in which noises are heard in the absence of corresponding external acoustic stimuli. Most experts distinguish between subjective and objective tinnitus (1). Objective tinnitus is a condition in which noises are generated within the body and transmitted to the ear, e.g., via spasms of the tensor muscle of the tympanic membrane. Objective tinnitus is rare and generally amenable to causally oriented treatment (1). Subjective tinnitus, like acoustic hallucinations, is a phantom phenomenon. Acoustic hallucinations occur particularly in patients with schizophrenia or after consumption of hallucinogenic substances and tend to involve the perception of sounds in organized form, such as music or speech. Tinnitus, on the other hand, consists of unorganized acoustic impressions of various kinds. The ear noise may be perceived as unilateral, bilateral, or arising in the head.

Epidemiology

Between 5% and 15% of the general population report tinnitus (2), and around 1% state that their quality of life is considerably impaired by their ear noises (3). This divergence between high overall prevalence and a relatively low proportion of tinnitus sufferers with severe problems may result from habituation, but may also be attributable to a relatively low degree of bother from the outset (e1). In addition, accompanying diseases such as sleep disorders, depression, or anxiety disorders can have negative effects on almost all aspects of daily life (4, 5).

Problems in dealing with tinnitus

Many physicians feel helpless in the face of tinnitus (6), and this frequently leads to therapeutic nihilism (7). Some tinnitus patients report that the worst moment of their individual disease history was not the onset of the ear noises, but rather when the treating physician informed them that there was “nothing more to be done” and that they would “just have to live with it.”

In actual fact there are many different treatment approaches, some of which can be readily integrated into daily clinical practice. Our intention with this article is to provide a practice-related treatment guideline for dealing with tinnitus patients, to review the currently

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available evidence-based treatment options, and, not least, to assess their clinical efficacy. To that end we carried out a selective review of the literature in the PubMed database (search term: “chronic tinnitus”). We also evaluated relevant book chapters and took account of our own clinical experience.

Pathophysiology

For many years tinnitus was understood as an inner ear disease. Under the misapprehension that the noises were generated in the inner ear, some patients had their acoustic nerve transected. However, this generally did not lead to cessation of the phantom phenomena (8), which underlines the crucial importance of the central nervous system for the pathophysiology of chronic tinnitus (8). We now know that tinnitus involves augmented stimulation all the way along the central auditory pathway which—similarly to phantom pain—arises as a compensatory reaction to the partial hearing loss experienced in most cases (9–11). Abnormal activity in somatosensory afferent nerves can also lead to increased activity in the central auditory pathway (e2–e4). This explains the clinical observation that symptoms in the cervical spine or temporomandibular joint may play a part in the origin of tinnitus (12, e5, e6).

However, the functional changes in patients with chronic tinnitus are not restricted to auditory structures, but extend to limbic, parietal, and frontal regions (13, e7, e8). The functional connection of these areas to the auditory cortex is more intensive in tinnitus patients than in healthy persons (13, 14). The mental stress associated with tinnitus is reflected by the coactivation of an unspecific distress network which includes, among other structures, the anterior cingulum, anterior insula, and amygdala. Apart from its role in tinnitus, this network plays a part in pain syndromes and somatoform disorders (e9) (*Figure 1*).

Case history and diagnostic work-up

In every case of tinnitus the following features must be determined:

- Duration of the tinnitus (acute versus chronic)
- Pulsatility
- Modulability of the tinnitus
- Attendant symptoms such as sleep disorders and concentration problems

Every patient should undergo ENT examination, audiological investigation of their hearing, and determination of the frequency and volume of the ear noise. Tinnitus synchronized with the pulse may be a symptom of vascular malformations (vascular loops, aneurysms, etc.), and patients in whom it is found should be referred for neuroradiological examination. Magnetic resonance imaging to exclude a vestibular schwannoma is recommended in patients with unilateral tinnitus and a distinct right–left discrepancy in hearing acuity. In cases where the ear noise can be modulated by movements of the jaw or cervical spine, physiotherapy or examination by an orthopedist/ortho-

FIGURE 1

Neuronal networks in chronic tinnitus

Besides altered activity in the auditory system, patients with chronic tinnitus exhibit changes in brain areas with responsibility for affect regulation (amygdala, hippocampus, etc.) and in frontoparietal regions relevant for regulation of attention and for conscious perception. Source: MEGANIM/Gehirn&Geist, reproduced by kind permission of MEGANIM Medical Graphics and Animation, Heidelberg, Germany

dontist should be considered. Validated questionnaires are available for assessment of the subjective severity of tinnitus (15) (for further detail see *Figure 2* and *Box*).

Treatment indications

The individual degree of bother is crucial in deciding whether symptomatic treatment is indicated, to avoid pathologizing the ear noise in patients whose quality of life is not impaired to any great extent. It often seems helpful to mention the trials that have shown that even people without tinnitus tend to experience phantom noises in particular situations (e.g., complete auditory deprivation in a soundproof booth) (16). Many patients are relieved simply to be told that their ear noise is benign in nature and that most patients habituate over time, so often no further treatment is required.

Attendant symptoms

The degree to which patients suffer from their tinnitus shows pronounced interindividual variation that cannot be explained by the characteristics of the ear noise (volume, frequency, etc.) (17). The considerable differences in burden of suffering often seem more closely linked to the varying severity of accompanying symptoms such as sleep disorders and concentration problems.

Patients whose tinnitus is accompanied by misophonia (perception of specific noises as unpleasant), phonophobia (fear of specific noises), or hyperacusis (perception of all sounds as louder) are particularly

FIGURE 2

Tinnitus: from initial findings to treatment

Evidence-based diagnostic and therapeutic algorithm (modified from www.tinnitusresearch.org/en/projects/flowchart_en.php and [e29]). The empirical basis is stronger for behavioral therapy than for neuromodulation/neurostimulation

BOX

Clinical classification of the severity of tinnitus

Classification of the severity of tinnitus according to Biesinger et al. (e30) is constructed along clinical and practical lines and takes account of the occupational and social effects of the ear noise.

Grade 1: The tinnitus is well compensated; the patient does not think of him- or herself as ill.

Grade 2: The tinnitus occurs mainly in quiet surroundings and is bothersome when the patient is stressed.

Grade 3: The tinnitus causes lasting impairments in the patient's private life and at work. Emotional, cognitive and physical problems ensue.

Grade 4: The tinnitus leads to complete decompensation in the patient's private life and to occupational disability.

likely to display avoidance behavior and may even develop a full-blown anxiety disorder. Avoidance behavior in the sense of blocking out noise from the normal environment is thus counterproductive for tinnitus patients and may reinforce the disease in that the central auditory system becomes further sensitized (16, 18).

Knowledge base

There currently exists no valid objective measure of the presence of tinnitus or the effects of potential treatments. The methodological quality of treatment trials is heterogeneous in the extreme, as emphasized in all available Cochrane meta-analyses that touch on tinnitus (19–25). Accordingly, efforts are being made to improve quality standards in clinical trials of the treatment of tinnitus (25–28).

The evidence for most existing treatments for tinnitus is limited. Many treatment trials have shown positive effects for individual patients but not for the collective as a whole. To some extent this seems attributable to the heterogeneity of the syndrome of tinnitus. It is assumed that the generic term “tinnitus” embraces various clinically and pathophysiologically distinct subtypes that respond in different ways to different forms of treatment (e10).

Treatment options

Psychoeducation/counseling

The picture conveyed to many tinnitus sufferers is one of hopelessness, leading in some cases to predominantly negative disease models and coping strategies (e11). Psychoeducative counseling is recommended as a basic component of every treatment for tinnitus (e12, e13). In our personal experience, sympathetic and understandable explanation of the fundamentally benign nature of idiopathic tinnitus is often all that is needed. Such a conversation between physician and patient represents the basis for establishment of constructive compensation and habituation mechanisms.

Cognitive behavioral therapy

Cognitive behavioral therapy (CBT) is the best-evaluated treatment for tinnitus. The general aim of CBT in patients with tinnitus is to improve awareness and facilitate the modification of maladaptive patterns on the cognitive, emotional, and behavioral level. A Cochrane meta-analysis of eight controlled clinical trials with a total of 468 participants showed that CBT produced significantly better results than the control conditions of “no treatment” and “other interventions” (e.g. short-term psychoeducation) with regard to quality of life (effect strength of standardized mean difference [SMD] between 0.64 and 0.91) and the depression score (SMD 0.37 compared with waiting list), but had no superior effect on ear noise volume (SMD 0.1) (22). The efficacy of inpatient psychotherapy, widespread in Germany, has not yet been evaluated in randomized controlled trials.

Individualized auditory stimulation

Most tinnitus patients are particularly bothered by their ear noise in quiet surroundings. Many sufferers find that targeted auditory stimulation reduces their tinnitus, and this is one of the frequently employed treatments (29).

Tinnitus maskers—Tinnitus maskers generate either sounds from the natural environment or individually tailored noises. Despite the widespread use of masking procedures, only limited data are available from controlled trials (19, 30). According to a Cochrane meta-analysis, the efficacy of tinnitus masking has been neither clearly proved nor disproved (19). Thus it remains unclear whether complete or partial masking of tinnitus is more effective in the longer term (e14). Our practical recommendation is therefore that patients should use whatever masking strategies they personally find acceptable. Dedicated devices are commercially available, but more economical alternatives such as indoor fountains or recordings of waves breaking can also be used.

Hearing aid—Hearing aids are used to compensate for hearing loss by improving the peripheral auditory input in the affected range of frequencies. To date, the influence of hearing aids on the perception of tinnitus has not been demonstrated in randomized controlled trials (30, e15). Observational studies suggest that particularly patients whose tinnitus frequency lies under 6 kHz benefit from using a hearing aid (e16). If the tinnitus is associated with severe loss of hearing, cochlear implants may be highly effective in individual cases (31, e17, e18).

Auditory training—Various forms of auditory training have been investigated in tinnitus patients, including frequency discrimination training (e19, e20), intensity discrimination training (e21), and training in object identification and localization (e22). However, their efficacy has not yet been confirmed in high-quality randomized controlled trials (30, e21).

Tinnitus retraining therapy

Tinnitus retraining therapy (TRT) comprises a combination of counseling and auditory stimulation by maskers or hearing aids. Three studies have demonstrated positive effects of this treatment (32, e23, e24), but there are no high-quality controlled trials; a recent Cochrane meta-analysis therefore states that the clinical efficacy of TRT cannot be viewed as unequivocally confirmed (23).

Neuromodulatory treatment

Based on the finding that chronic tinnitus results from or at least goes hand in hand with changes in central nervous activity, various types of neuromodulatory treatment for tinnitus have been developed in recent years.

Neurobiofeedback—Pilot studies on the use of neurobiofeedback to treat tinnitus have shown significant reductions in the intensity and loudness of ear noise (33, e25, e26). Detailed evaluation of the

clinical efficacy of such procedures in large randomized controlled trials has yet to take place.

Repetitive transcranial magnetic stimulation—Repetitive transcranial magnetic stimulation (rTMS) is a procedure in which magnetic impulses are used to modulate the activity of superficially located brain regions. Several randomized controlled trials have found evidence for clinical efficacy of rTMS (34). However, the effects of rTMS are slight, the interindividual variability is pronounced, and the duration of the treatment effect is often limited (23, 25).

Auditory stimulation—Specific forms of auditory stimulation have also been developed for the treatment of tinnitus. One suggestion is to modify the frequency spectrum of music according to the individual patient's audiometric profile, thus compensating for the individual hearing impairment (36). In other auditory stimulation procedures, precisely the frequencies in which the tinnitus tone is localized are removed from the frequency spectrum ("tailor-made notched music training"). In a pilot study in a small group of patients, daily stimulation outside the tinnitus spectrum for a period of a year showed a significant reduction in ear noise volume compared with a control condition (37).

Coordinated reset stimulation—In another form of auditory stimulation, known as coordinated reset stimulation, the patient is presented with short tones above and below his/her individual tinnitus frequency. An initial pilot study has shown promising results (38), but further evaluation in larger groups of patients has yet to take place.

Despite the promising pilot data, all of these neuromodulatory approaches to the treatment of tinnitus must be regarded as experimental. No large, multicenter, randomized double-blind trials have yet been conducted.

Pharmacotherapy

The observation that intravenous administration of the tension-dependent sodium-channel blocker lidocaine led to temporary suppression of tinnitus in a majority of patients (e27, e28) suggests that tinnitus is amenable to pharmacological treatment in principle. The therapeutic use of lidocaine is limited, however, by the transient nature of its action and by the adverse effects of the intravenous route of administration.

Despite the investigation of a large number of pharmaceuticals, no medicinal approach can yet be regarded as an established treatment option. Accordingly, neither in Europe nor in the USA has any drug yet been approved for the treatment of tinnitus (39). The indication for pharmacotherapy is therefore restricted to the treatment of comorbidities such as anxiety disorders, sleep disorders, and depression.

Interdisciplinary approach to diagnosis and treatment

A stepwise multidisciplinary treatment program consisting essentially of counseling, behavioral therapy, and auditory stimulation was recently evaluated in a

large randomized controlled trial (40). Compared with standard treatment over an observation period of 12 months, the stepwise multidisciplinary treatment program showed significant improvements in

- quality of life (effect strength $d = 0.24$; $p = 0.0009$),
- severity of tinnitus ($d = 0.43$; $p = 0.0001$),
- degree of disability caused by tinnitus ($d = 0.45$; $p < 0.0001$).

The specialized treatment program started with audiological measurements/treatment and counseling, followed by optional multidisciplinary group or individual treatment sessions for a period of 12 weeks. These sessions involved clinical psychologists, exercise therapists, physiotherapists, audiologists, social workers, and speech therapists. The results of this study underline the importance of an interdisciplinary, stepwise approach to the treatment of tinnitus.

Summary

The management of chronic tinnitus remains a challenge despite the availability of various forms of treatment, but there is no justification for therapeutic nihilism. No doctor today should say "there's nothing we can do." Cooperation among various disciplines is vital in the diagnosis and treatment of tinnitus.

It is also crucial for patients with chronic tinnitus whether the physician directly responsible for their treatment reacts to their description of their symptoms with patient helplessness or whether the offer of a therapeutic relationship is maintained throughout. It is very important that they experience the treating physician as a reliable source of information and a professional counselor with whom they can discuss the indications and decide on what diagnostic or therapeutic steps to take next. Many patients are relieved simply to be told there is no somatic cause for their tinnitus and that their ear noise is essentially benign in nature, paving the way for the development of positive coping and habituation strategies.

Conflict of interest statement

Dr. Langguth has received consulting fees from ANM, Autifony, Merz, Novartis, and Sanofi, and lecture fees from Merz and ANM. He holds patents for the method of neuronavigational positioning of the TMS coil for treatment of tinnitus and of treatment with cyclobenzaprine and naltrexone. Furthermore, he has received revenue from sales of the "Textbook of Tinnitus".

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REFERENCES

1. Eggermont JJ, Roberts LE: The neuroscience of tinnitus. *Trends Neurosci* 2004; 27: 676–82.

2. Hoffmann HJ, Reed G: Epidemiology of tinnitus. In: Snow JB (ed.): Tinnitus: Theory and Management. Hamilton: BC Decker 2004; 6–41.
3. Hebert S, Carlon B, Hasson D, Magnusson Hanson LL, Westerlund H, Theorell T: Tinnitus severity is reduced with reduction of depressive mood—a prospective population study in Sweden. *PLoS One* 2012; 7: e37733.
4. Cima RF, Vlaeyen JW, Maes IH, Joore MA, Anteunis LJ: Tinnitus interferes with daily life activities: a psychometric examination of the Tinnitus Disability Index. *Ear Hear* 2011; 32: 623–33.
5. Javaheri S, Cohen V, Libman I, Sander V: Life-threatening tinnitus. *Lancet* 2000; 356: 308.
6. Hall DA, Lainez MJ, Newman CW, Sanchez TG, Egler M, Tennigkeit F, et al.: Treatment options for subjective tinnitus: self reports from a sample of general practitioners and ENT physicians within Europe and the USA. *BMC Health Serv Res* 2011; 11: 302.
7. Langguth B: Tinnitus: the end of therapeutic nihilism. *Lancet* 2012; 379: 1926–8.
8. House JW, Brackmann DE: Tinnitus: surgical treatment. *Ciba Found Symp* 1981; 85: 204–16.
9. Norena AJ: An integrative model of tinnitus based on a central gain controlling neural sensitivity. *Neurosci Biobehav Rev* 2011; 35: 1089–109.
10. Schaette R, Kempter R: Development of tinnitus-related neuronal hyperactivity through homeostatic plasticity after hearing loss: a computational model. *Eur J Neurosci* 2006; 23: 3124–38.
11. Yang S, Weiner BD, Zhang LS, Cho SJ, Bao S: Homeostatic plasticity drives tinnitus perception in an animal model. *Proc Natl Acad Sci U S A* 2011; 108: 14974–9.
12. Vielsmeier V, Strutz J, Kleinjung T, Sackelmann M, Kreuzer PM, Landgrebe M, et al.: Temporomandibular joint disorder complaints in tinnitus: further hints for a putative tinnitus subtype. *PLoS One* 2012; 7: e38887.
13. Schlee W, Weisz N, Bertrand O, Hartmann T, Elbert T: Using auditory steady state responses to outline the functional connectivity in the tinnitus brain. *PLoS One* 2008; 3: e3720.
14. Schlee W, Mueller N, Hartmann T, Keil J, Lorenz I, Weisz N: Mapping cortical hubs in tinnitus. *BMC Biol* 2009; 7: 80.
15. S1-Leitlinie der Deutschen Gesellschaft für Hals-Nasen-Ohren-Heilkunde, Kopf- und Hals-Chirurgie (AWMF-Leitlinien-Register Nr. 017/064). www.awmf.org/leitlinien/detail/II/017-064.html (last accessed on 15 December 2012).
16. Heller MF, Bergman M: Tinnitus aurium in normally hearing persons. *Ann Otol Rhinol Laryngol* 1953; 62: 73–83.
17. Folmer RL, Griest SE, Meikle MB, Martin WH: Tinnitus severity, loudness, and depression. *Otolaryngol Head Neck Surg* 1999; 121: 48–51.
18. Schaette R, Turtlet C, Munro KJ: Reversible induction of phantom auditory sensations through simulated unilateral hearing loss. *PLoS One* 2012; 7: e35238.
19. Hobson J, Chisholm E, El Refaie A: Sound therapy (masking) in the management of tinnitus in adults. *Cochrane Database Syst Rev* 2012; 11: CD006371.
20. Hilton M, Stuart E: Ginkgo biloba for tinnitus. *Cochrane Database Syst Rev* 2004: CD003852.
21. Baldo P, Doree C, Lazzarini R, Molin P, McFerran DJ: Antidepressants for patients with tinnitus. *Cochrane Database Syst Rev* 2006: CD003853.
22. Martinez-Devesa P, Perera R, Theodoulou M, Waddell A: Cognitive behavioural therapy for tinnitus. *Cochrane Database Syst Rev* 2010: CD005233.
23. Phillips JS, McFerran D: Tinnitus retraining therapy (TRT) for tinnitus. *Cochrane Database Syst Rev* 2010: CD007330.
24. Hoekstra CE, Rynja SP, van Zanten GA, Rovers MM: Anticonvulsants for tinnitus. *Cochrane Database Syst Rev* 2011: CD007960.
25. Meng Z, Liu S, Zheng Y, Phillips JS: Repetitive transcranial magnetic stimulation for tinnitus. *Cochrane Database Syst Rev* 2011: CD007946.
26. Landgrebe M, Zeman F, Koller M, Eberl Y, Mohr M, Reiter J, et al.: The Tinnitus Research Initiative (TRI) database: a new approach for delineation of tinnitus subtypes and generation of predictors for treatment outcome. *BMC Med Inform Decis Mak* 2010; 10: 42.
27. Langguth B, Goodey R, Azevedo A, Bjorne A, Cacace A, Crocetti A, et al.: Consensus for tinnitus patient assessment and treatment outcome measurement: Tinnitus Research Initiative meeting, Regensburg, July 2006. *Prog Brain Res* 2007; 166: 525–36.
28. Langguth B, Kleinjung T, Landgrebe M: Tinnitus: the complexity of standardization. *Eval Health Prof* 2011; 34: 429–33.
29. Newman CW, Sandridge SA: A comparison of benefit and economic value between two sound therapy tinnitus management options. *J Am Acad Audiol* 2012; 23: 126–38.
30. Hoare DJ, Kowalkowski VL, Kang S, Hall DA: Systematic review and meta-analyses of randomized controlled trials examining tinnitus management. *Laryngoscope* 2011; 121: 1555–64.
31. Van de Heyning P, Vermeire K, Diebl M, Nopp P, Anderson I, De Ridder D: Incapacitating unilateral tinnitus in single-sided deafness treated by cochlear implantation. *Ann Otol Rhinol Laryngol* 2008; 117: 645–52.
32. Bauer CA, Brozoski TJ: Effect of tinnitus retraining therapy on the loudness and annoyance of tinnitus: a controlled trial. *Ear Hear* 2011; 32: 145–55.
33. Dohrmann K, Weisz N, Schlee W, Hartmann T, Elbert T: Neurofeedback for treating tinnitus. *Prog Brain Res* 2007; 166: 473–85.
34. Peng Z, Chen XQ, Gong SS: Effectiveness of repetitive transcranial magnetic stimulation for chronic tinnitus: a systematic Review. *Otolaryngol Head Neck Surg* 2012; 147: 817–25.
35. Plewnia C: Brain stimulation: new vistas for the exploration and treatment of tinnitus. *CNS Neurosci Ther* 2011; 17: 449–61.
36. Davis PB, Paki B, Hanley PJ: Neuromonics tinnitus treatment: third clinical trial. *Ear Hear* 2007; 28: 242–59.

KEY MESSAGES

- Chronic tinnitus is a common disorder in the general population; some patients suffer severe impairment of their quality of life.
- Following exclusion of treatable causes of the ear noise, management is symptomatic after careful assessment of the indication depending on the individual degree of bother.
- Treatment options include counseling, cognitive behavioral therapy, and various forms of auditory stimulation. Neuromodulatory techniques are in the early stages of development.
- The indication for pharmacological treatment of chronic tinnitus is currently restricted to tinnitus-associated symptoms such as depressive mood, sleep disorders, and anxiety disorders.
- Because tinnitus has multiple possible causes and comorbidities, multidisciplinary diagnosis and treatment are of crucial importance.

37. Okamoto H, Stracke H, Stoll W, Pantev C: Listening to tailor-made notched music reduces tinnitus loudness and tinnitus-related auditory cortex activity. *Proc Natl Acad Sci USA* 2010; 107: 1207–10.
38. Tass PA, Adamchic I, Freund HJ, von Stackelberg T, Hauptmann C: Counteracting tinnitus by acoustic coordinated reset neuro-modulation. *Restor Neurol Neurosci* 2012; 2: 137–9.
39. Elgoyhen AB, Langguth B: Pharmacological approaches to the treatment of tinnitus. *Drug Discov Today* 2010; 15: 300–5.
40. Cima RF, Maes IH, Joore MA, Scheyen DJ, El Refaie A, Baguley DM, et al.: Specialised treatment based on cognitive behaviour therapy versus usual care for tinnitus: a randomised controlled trial. *Lancet* 2012; 379: 1951–9.

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eReferences

- e1. Gopinath B, McMahon CM, Rochtchina E, Karpa MJ, Mitchell P: Incidence, persistence, and progression of tinnitus symptoms in older adults: the Blue Mountains Hearing Study. *Ear Hear* 2010; 31: 407–12.
- e2. Zeng C, Nannapaneni N, Zhou J, Hughes LF, Shore S: Cochlear damage changes the distribution of vesicular glutamate transporters associated with auditory and nonauditory inputs to the cochlear nucleus. *J Neurosci* 2009; 29: 4210–7.
- e3. Zeng C, Yang Z, Shreve L, Bledsoe S, Shore S: Somatosensory projections to cochlear nucleus are upregulated after unilateral deafness. *J Neurosci* 2012; 32: 15791–801.
- e4. Shore SE: Plasticity of somatosensory inputs to the cochlear nucleus-implications for tinnitus. *Hear Res* 2011; 281: 38–46.
- e5. Levine RA: Somatic (craniocervical) tinnitus and the dorsal cochlear nucleus hypothesis. *Am J Otolaryngol* 1999; 20: 351–62.
- e6. Sanchez TG, Rocha CB: Diagnosis and management of somatosensory tinnitus: review article. *Clinics (Sao Paulo)* 2011; 66: 1089–94.
- e7. Adjarian P, Sereda M, Hall DA: The mechanisms of tinnitus: perspectives from human functional neuroimaging. *Hear Res* 2009; 253: 15–31.
- e8. Lanting CP, de Kleine E, van Dijk P: Neural activity underlying tinnitus generation: results from PET and fMRI. *Hear Res* 2009; 255: 1–13.
- e9. Landgrebe M, Barta W, Rosengarth K, Frick U, Hauser S, Langguth B, et al.: Neuronal correlates of symptom formation in functional somatic syndromes: a fMRI study. *Neuroimage* 2008; 41: 1336–44.
- e10. Tyler R, Coelho C, Tao P, Ji H, Noble W, Gehring A, et al.: Identifying tinnitus subgroups with cluster analysis. *Am J Audiol* 2008; 17: 176–84.
- e11. Häuser W, Hansen E, Enck P: Nocebo phenomena in medicine: their relevance in everyday clinical practice. *Dtsch Arztebl Int* 2012; 109(26): 459–65.
- e12. Searchfield G, Magnusson J, Shakes G, Biesinger E, Kong O: Counseling and psycho-education for tinnitus management. In: Moller A, Langguth B, de Ridder D, Kleinjung T (eds): *Textbook of tinnitus*. 1st edition. Springer 2011: 535–6.
- e13. Zenner HP, Pfister M, Birbaumer N: Tinnitus sensitization: Sensory and psychophysiological aspects of a new pathway of acquired centralization of chronic tinnitus. *Otol Neurotol* 2006; 27: 1054–63.
- e14. Tyler RS, Noble W, Coelho CB, Ji H: Tinnitus retraining therapy: mixing point and total masking are equally effective. *Ear Hear* 2012; 33: 588–94.
- e15. Melin L, Scott B, Lindberg P, Lyttkens L: Hearing aids and tinnitus—an experimental group study. *Br J Audiol* 1987; 21: 91–7.
- e16. Schaette R, König O, Hornig D, Gross M, Kempter R: Acoustic stimulation treatments against tinnitus could be most effective when tinnitus pitch is within the stimulated frequency range. *Hear Res* 2010; 269: 95–101.
- e17. Olze H, Zahnert T, Hesse G: Hörgeräte, implantierbare Hörgeräte und Cochlear Implants in der Therapie des chronischen Tinnitus. *HNO* 2010; 58: 1004–12.
- e18. Kompis M, Pelizzone M, Dillier N, Allum J, DeMin N, Senn P: Tinnitus before and 6 months after cochlear implantation. *Audiol Neurotol* 2012; 17: 161–8.
- e19. Flor H, Hoffmann D, Struve M, Driesch E: Auditory discrimination training for the treatment of tinnitus. *Appl Psychophysiol Biofeedback* 2004; 29: 113–20.
- e20. Herraiz C, Diges I, Cobo P: Auditory discrimination therapy (ADT) for tinnitus management. *Prog Brain Res* 2007; 166: 467–71.
- e21. Roberts LE, Bosnyak DJ: Auditory training in tinnitus. In: Moller A, et al. (eds.): *Textbook of tinnitus*. 1 edition. New York: Springer 2011; 563–73.
- e22. Searchfield GD, Morrison-Low J, Wise K: Object identification and attention training for treating tinnitus. *Prog Brain Res* 2007; 166: 441–60.
- e23. Henry JA, Schechter MA, Zaugg TL, Griest S, Jastreboff PJ, Vernon JA, et al.: Outcomes of clinical trial: tinnitus masking versus tinnitus retraining therapy. *J Am Acad Audiol* 2006; 17: 104–32.
- e24. Herraiz C, Hernandez FJ, Plaza G, de los Santos G: Long-term clinical trial of tinnitus retraining therapy. *Otolaryngol Head Neck Surg* 2005; 133: 774–9.
- e25. Crocetti A, Forti S, Del Bo L: Neurofeedback for subjective tinnitus patients. *Auris Nasus Larynx* 2011; 38: 735–8.
- e26. Gosepath K, Nafe B, Ziegler E, Mann WJ: Neurofeedback in der Therapie des Tinnitus. *HNO* 2001; 49: 29–35.
- e27. Israel JM, Connelly JS, McTigue ST, Brummett RE, Brown J: Lidocaine in the treatment of tinnitus aurium. A double-blind study. *Arch Otolaryngol* 1982; 108: 471–3.
- e28. Melding PS, Goodey RJ, Thorne PR: The use of intravenous lignocaine in the diagnosis and treatment of tinnitus. *J Laryngol Otol* 1978; 92: 115–21.
- e29. Langguth B, Biesinger E, Del Bo L, De Ridder D, Goodey R, Herraiz C, et al.: Algorithm for the diagnostic and therapeutic management of tinnitus. In: Moller A, Langguth B, de Ridder D, Kleinjung T (eds): *Textbook of tinnitus*. 1st edition. Springer 2011.
- e30. Biesinger E, Heiden C, Greimel V, Lendle T, Hoing R, Albegger K: Strategien in der ambulanten Behandlung des Tinnitus. *HNO* 1998; 46: 157–69.