Tinnitus:
Why we should NOT say NO to our patients!

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Tinnitus

1. Tinnitus: Introduction and History
2. Brief review of the Auditory System
3. Causes of Tinnitus & Theories of Tinnitus Generation
4. The Neuroscience of Tinnitus
   - Electrophysiologic Recordings for Tinnitus
   - Neuroimaging of Tinnitus
5. Tinnitus Studies at FAU
6. Recent Advances in Tinnitus management and treatments
Tinnitus
Malady of the 21st Century
Tinnitus
Tinnitus

Historical Perspective

• In some of the world’s oldest medical texts people complain about noise in their ears (evidenced in papyrus scrolls from ancient Egypt, clay tablets from Assyria)

The word Tinnitus first coined by: Gaius Plinius Secundus, or Pliny the Elder, AD 23, Como
Tinnitus
Historical Perspective

• Aristotle in the 5th century BC: "Buzzing in the ears ceases when a greater sound drives out the less"
Tinnitus
Historical Perspective

Avicenna
Born: AD 980, Bukhara, Persia
Died: December 10, 1037, Hamedan

Jean Marc Gaspard Itard
Born: April 24, 1774, Oraison
Died: July 5, 1838, Paris
Martin Luther, Ludwig van Beethoven & Vincent van Gogh

All had Tinnitus!
A Brief Review of the Auditory System
Sound Transmission to the Auditory System
So, How Does the Ear Work again?

http://www.vimm.it/cochlea/cochleapages/overview/history.htm
Central Auditory Pathway

*Auditory Nerve
*Cochlear Nucleus Complex
*Superior Olivary Complex
*Lateral Lemniscus
*Inferior Colliculus
*Medial Geniculate Body
*Auditory Cortex (Heschl’s Gyri)

Tonotopic Map Has Columnar Organization

Primary Auditory Cortex
Causes of Tinnitus

- Noise Exposure
- Aging
- Ototoxicity
- Genetics
- Metabolic Disorders
- Hearing Loss
- .....
Tinnitus & Noise Induced Hearing Loss
Recreational noise, iPods/MP3

How loud is loud?

Pure Tone Audiometry

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0 - 25 dB Normal Hearing
25+ - 90 dB Hearing Loss
90 dB Deaf

Sound Pressure Level

Sound Pressure

Threshold of Pain

Jet Engine (25 m distance)
140 dB

Jet Take-Off (100 m distance)
130 dB

Pneumatic Chipper
120 dB

Average Street Traffic
110 dB

Heavy Truck
90 dB

Conversational Speech
80 dB

Business Office
70 dB

Library
60 dB

Bedroom
50 dB

Living Room
40 dB

Threshold of Hearing
20 dB

Threshold of Hearing
0 dB

How loud is loud?
Ototoxic Medications

(initial damage to the outer hair cells, loss of otoacoustic emissions, results in sensori-neural hearing loss & tinnitus)

- Aminoglycosides
- Anti-cancer medications
- Quinine (tonic water)
- Heavy metals
Accompanying symptoms

- Stress
- Anxiety
- Depression
- Fear
- Insomnia
- Fatigue
- …
Theories of Tinnitus Generation
Tinnitus Classification

- Subjective Tinnitus
- Objective Tinnitus
Tinnitus due to Left Vestibular Schwanoma

Pulsatile Tinnitus

FIGURE 18-2. Carotid stenosis with an ulcerated plaque (arrow) as a cause of pulsatile tinnitus. Turbulent blood flow at the site of the stenotic internal carotid artery generates sound waves that are transmitted to the cochlea. A loud bruit may be heard, and a thrill may be palpable. Image courtesy of Rohit Bakshi, MD.
Theories for Tinnitus Generation

(Cited in Sattinger, 2008, ENT Today)

• I. Increase in neural activity in the auditory system (neurons are firing at a higher rate, the same way when we hear a sound)

• II. An increase in neural synchrony in the brain leads to tinnitus. Tinnitus is a dyssynchronous signal that can arise from anywhere in the peripheral or central nervous system and expresses itself through the auditory system.
Cortical Plasticity & Phantom Limb Pain

Amputation of Finger

- Index finger & thumb normally activate restricted regions of somatosensory cortex

- Amputation of index finger causes expansion of thumb region

- Thumb region invades cortical region normally activated by index finger

From Salvi, 2006
Neuroimaging Studies of Tinnitus
How are the functional neuroimaging techniques used in Tinnitus studies?

Dr. Frank Mirz Tinnitus Lab, Copenhagen-Denmark
Normal State
(No Tinnitus)

Evoked Tinnitus!
Altered Tinnitus
Evoked-Tinnitus Classification

- Visual-motor evoked (e.g., Gaze-evoked tinnitus)
- Somatosensory-evoked tinnitus/Cutaneous-evoked (fingers or external ear) tinnitus
- Finger-movement-evoked tinnitus
  Somatomotor-evoked tinnitus
- Orofacial/Jaw movement evoked tinnitus
- Cranio-cervical manipulations of head and neck
- Applying electrical stimulation to the median nerve and hand region
Orofacial/Jaw-Evoked Tinnitus
Orofacial/Jaw-Evoked Tinnitus
Gaze-Evoked Tinnitus
Gaze-Evoked Tinnitus
Underlying factors of evoked tinnitus

• Peripheral deafferentation
• Crossmodal reactive sprouting of neurons to denervated synaptic sites (Wall et al., 1987) (Hypotheses)
• Non-classical auditory pathways become reactivated as an expression of neuroplasticity (Moller and Rolins, 2002) (Speculation)
Recent Research: The effects of Parental Mental Health in childhood in coping with tinnitus and hyperacusis in adulthood

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Hashir Aazh, PhD
Director of Tinnitus and Hyperacusis Specialist Clinic, Surrey Hospital, Guildford, UK

Brian C. J. Moore, PhD, Professor, Department of Psychology, University of Cambridge, Cambridge, UK
Topics that were investigated:

1. Exploring the connection between parental separation and parental mental health on tinnitus and hyperacusis disability
2. Exploring the effects of parental mental health as a risk factor for anxiety and depression in tinnitus and hyperacusis patients
• Parental separation and parental mental health are two key factors that may influence coping with tinnitus and hyperacusis in adulthood.

• It is not clear if there is a relationship between parental separation and its impact on perceived disability from tinnitus and hyperacusis in adulthood.
The risk of parental mental health on factors such as anxiety and depression and its effect on tinnitus and hyperacusis has not thoroughly been investigated.
Material & Method:

- Employing a retrospective cross-sectional study with a correlational design, the effects of parental mental health on tinnitus and hyperacusis of a group of sequential patients who attended a clinic in UK were investigated (N=287, Mean Age=52.5 years).
Material & Method:

- The association between mental health and tinnitus/hyperacusis perception was explored by measuring the associated anxiety and depression via the Generalized Anxiety Disorder questionnaire (GAD-7) and the Patient Health questionnaire (PHQ-9).
Study Conclusion:

- Clinicians offering tinnitus and hyperacusis rehabilitation should screen patients for parental mental illness in childhood, especially for those with comorbid depression.

- There were no significant differences in the scores for THI and HQ between patients with and without history of parental separation but there were significant differences in THI and HQ scores between patients with and without history of parental mental health illness.
Tinnitus Research Initiative (TRI): Algorithm for Diagnostic & Therapeutic Management of Tinnitus

**History**
- Self-performed questionnaires
  - Tinnitus Handicap Inventory
  - Tinnitus Questionnaire
  - Case History Questionnaire
  - Tinnitus Severity Grading (E. Biesinger)

**Clinical examination**
- Otoscopy
- Cranio-mandibular & neck examination
- Auscultations

**Audiological measurements**
- Audiometry
- Psychophysical measurements
- Tympanometry
- Tubal impedance-manometry
- Distortion product OAE

**Counselling**
- Cran. + cerv. CT/MRI
- BAEP
- EEG
- Echo doppler
- Neck exam
- Psych. exam

**Tinnitus**
- Pulsatile tinnitus
  - Arterial
  - Venous

- Acute Tinnitus with sudden hearing loss

- Paroxysmal

- Constant

**Non-pulsatile tinnitus**

- Hearing loss
  - Conductive
  - Sensory neural

- + Vertigo
  - MRI
  - BAEP
  - VEMP
  - Electro cochleography

- + Headache
  - MRI
  - Furosemide test
  - Liquor puncture

- + Psychiatric
  - Psych. Exam.

- + Somatosens. Neck TMJ

- Posttraumatic tinnitus

**Acute treatment**
- EEG
- MRI
- BAEP
- Blood test

- Neurovascular examination
  - Echo-doppler
  - Angiography
  - Angio-MRI
  - Blood test

- Arteriovenous malformation
- Sinus thrombosis
- Aneurysm
- Glomus tumor
- Carotid stenosis
- BIH
- Sinus thrombosis
- High Ijg bulb
- BIH
- Overcrowding
- Chian
- Epilepsy
- MVC
- Aud. nerve compression
- Myoclonus
- Otosclerosis
- Otitis
- Middle ear aplasia
- Eustachian tube dysfunction
- Noise trauma
- Chronic hearing loss
- Prevention
- MIVC
- Ménière
- Endolymphatic hydrops
- Canal dehiscence
- N VIII tumor
- BIH
- Chari
- Space occupying lesion
- Basilar impression
- Depression
- Anx. disorder
- Insomnia
- Somatoform disorder
- Suicidality

- Disorders Neck TMJ
- PTSD
- Petrous bone fracture
- Osseous chain disruption
- Posttraumatic epilepsy
- Carotid dissection
- Perilymphatic fistula
- Neck trauma
- Otic barotrauma
- Cochlear concussion

**If causal treatment not possible / not successful: symptomatic treatment**

- Auditory stimulation
- Cognitive behavioral therapy
- Pharmacotherapy
- Neurobiofeedback
- Neuromodulation

**Abbreviations:** BAEP = Brainstem auditory evoked potential, BIH = Benign intracranial hypertension, MVC = Microvascular compression, OAE = Otoacoustic emissions, PTSD = Posttraumatic stress disorder, SOL = Space occupying lesion, TMJ = Temporomandibular joint, VEMP = Vestibular evoked myogenic potential

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Tinnitus Treatments!
Turn off my tinnitus! (Where is that “magic pill”?)
Comments made by some clinicians to their tinnitus patients about tinnitus treatment (Danesh, 2002 Tinnitus study)

• “Go and live with it”!
• “Nothing can be done”!
• “If I knew how to cure it, I will be a rich person”!
• “It is in your head”!

Tragedies: “Man murders doctor who prescribed him **************, claimed it ruined his life (caused tinnitus)” (David Cornbleet, MD in Chicago, 2008) & John Kemink, MD, in Michigan (1992)
Tinnitus Treatment Categories

- Medications
- Psychological Approaches (e.g., Cognitive Behavioral Therapy)
- Sound Therapy
- Physical Manipulation
- Electrical Stimulation
- Surgical Approaches
- ...

* Amplification (Hearing Aids)
* Biofeedback
* Cochlear Implants/Electrical Stimulation
* Cognitive Behavioral Therapy
* Tinnitus Reaction Modification
* Drug Therapy
* Masking/Habituation Therapy
* Tinnitus Retraining Therapy
* TMJ Treatment
* Alternative Treatments
* Surgery

Source: [www.ata.org](http://www.ata.org)
Electrical Stimulation of the Cortex in Rats

Mouse is the human’s best friend!
FIG. 2. An example showing chronic implantation of a 4×4 microwire electrode array in the rat AC and electrophysiological responses to acoustic stimulation. A AC areas before implantation. B Placement of a chronic microwire electrode array. C Frequency tuning curves were recorded and used to determine the frequency representations of the implanted electrodes in the AC. Responses in channels such as 1, 2, 3, 4, 5, 9, 11, 12, 13, 14, 15, and 16 were well or sharply tuned to tones, suggesting that these neurons are located in the core area of the AC. Responses in channels such as 6, 7, 8, and 10 were less sensitive or broadly tuned to tones, suggesting that these neurons are probably near or located in the belt region. Scale bar for activity rate is on CH8.
Vagus Nerve Stimulation in Rats

Targeted nerve stimulation

rTMS

- Repetitive transcranial magnetic stimulation (rTMS) is an innovative method for locally modulating brain activity including Tinnitus.
Susan Shore, PhD
Neuromod
Lenire
Medication Therapy for Tinnitus
Medication Therapy for Tinnitus!

Where is the magic pill?


The CPG recommends against the following treatments:
1) pharmaceutical medications
2) dietary supplements
3) transcranial magnetic stimulation

http://www.audiology.org/sites/default/files/publications/R2R_Tinnitus_ClinicalResearch_EvidenceBasedPractice.pdf
N acetyl cysteine for tinnitus
Antioxidants, herbs, vitamins.
Cyclobenzaprine (Flexerill) and Tinnitus

- *Cyclobenzaprine* is a skeletal *muscle relaxant* (fibromyalgia)
- Activates Locus Coeruleus in the brainstem (stress and panic)
Supplements and CBD

- Supplements such as micronutrients, antioxidants, cannabinoids (CBD), etc.
- No direct effect discovered yet!
Cognitive Behavioral Therapy (CBT)

CBT is a psychological intervention that aims to alleviate anxiety by helping the patient to modify their dysfunctional cognitions, ruminations and safety-seeking behaviors.

CBT for:
Tinnitus, Hyperacusis, Misophonia

Aazh et al, 2019
Initial emotion

Trigger
Tinnitus

Thoughts
“I don’t like my tinnitus.” “It interrupts everything I do.” “It affects my relationship, family, job.” “It is a big monster.” “It is taking away my silence.” “There is no peace.” …

More evaluative thoughts
“I will not be able to make it.” “I will be isolated.” “I am not normal.”

Emotions
Upset, frightened, hopeless, annoyed, angry, sad

Physical sensations
Tense in shoulders and hands, earache, tearful, restless, problems hearing

Aazh et al, 2019
Hearing Loss and Tinnitus

- Listening hard or straining yourself to hear better will make your tinnitus awareness more common.

- Hearing Aids have helped many people to reduce the anxiety associated with social interactions and have improved tinnitus control and management.
The hidden effects of untreated hearing loss in addition to contributions to tinnitus generation.

The Consequences of Untreated Hearing Loss

**Depression**
Those with untreated hearing loss have **significantly higher** incidence of feelings of isolation and depression.

**Lifespan**
Studies show **adults with untreated impaired hearing have a shorter lifespan** than peers with hearing aids.

**Cognitive Decline**
Adults with untreated hearing loss experience a **30-40% faster decline** in cognitive abilities.

**Balance**
People with a mild hearing loss (less than 25 decibels) are three times more likely to have a history of falling. Furthermore, each additional 10 decibels of hearing loss will increase the **falling risk by 1.4 times**.

**Dementia**
Adults with untreated hearing loss are **up to 5 times more likely to develop dementia**.
Sound Therapy and Habituation Therapy

Very promising and noninvasive
Habituation

• “Habituation” is defined as the disappearance of a reaction to a stimulus.

Habituation to Sound

- New refrigerator is loud at first
- After a while it is less noticeable
- Not even aware it is present
What is the Goal of Habituation?

- Habituation therapy is a process in which tinnitus becomes an unimportant signal even though it is still there.
Jastreboff suggests two things that are important in the control of the tinnitus:

1- The patient must habituate to the tinnitus itself, and
2- The patient must habituate to the emotional consequences of the tinnitus.
Take Home Message

There are many methods which can help tinnitus patients. Incorporating a healthy and informative approach for tinnitus patients in your practice is essential.
Thank You

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