Tinnitus in Patients with Sensorineural Hearing Loss - Management and Quality of Life

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2012
To my angels
Ramesh,
Alma and Arvid
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Approximately 15% of Swedish people experience tinnitus, but only 2.4% of them experience severe problems. Treatment modalities for tinnitus are varied, but the most common treatment model is counselling. The majority of patients with tinnitus report some degree of hearing loss, and in addition, hearing aids have been used for many years in patients who suffer from both tinnitus and hearing impairment.

The aim of the present thesis was to investigate the disease management and identify the quality of life in patients with tinnitus and sensorineural hearing loss.

Both studies described here are retrospective, descriptive studies of patients who sought care for tinnitus and hearing loss at the two ENT clinics in Östergötland County, Sweden, during 2004-2007 and who also received a diagnosis code. A medical record review of all patients (study I contained 1672 subjects) revealed that 714 patients were diagnosed with both tinnitus and SNHL between 2004 and 2007 and could be included in study II.

The results showed that 70% of our cohort had tinnitus, but many of the patients initially did not receive a diagnosis for their tinnitus. Information about the patients’ vertigo, heredity for hearing loss and tinnitus, diabetes history, cardiovascular disease history and other factors related to their health was often missing from the medical records. Our findings showed that the Stepped Care Model, which however was only used in a minority of the cases, could be effective in patients with tinnitus and could provide a better care process for these patients. Of the cohort, 56% of the patients received a diagnosis of bilateral hearing loss. The pure tone average (PTA) of the left ear was significantly higher than that of the right ear. There were 314 patients (44%) who had hearing aids out of the total of 714, even though it is likely that hearing aids could be beneficial for these patients. We found that the overall scores for the Tinnitus Handicap Inventory (THI) were higher in female patients than male patients. All patients who participated in study II estimated their life quality and general health at a good level. This could be due to the fact that they were investigated 4-5 years after they first reported their tinnitus and that tinnitus annoyance decrease over time. Further, the outcomes of study II demonstrated that the majority of patients, who were dissatisfied with the care they obtained, had no hearing aids. This could indicate a support the use of hearing aids fitting as main treatment model in patients with both tinnitus and hearing loss.

Future research is needed to investigate how hearing aid professionals could motivate patients who suffer from both tinnitus and hearing loss to use hearing aids.
LIST OF ORIGINAL PAPERS

This thesis is based on the following papers, which will be referred to in the text by their roman numerals (I-II):


<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
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<tr>
<td>ABR</td>
<td>Auditory brainstem response</td>
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<tr>
<td>ANOVA</td>
<td>Analysis of variance</td>
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<tr>
<td>CANS</td>
<td>The central auditory nervous system</td>
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<td>CI</td>
<td>Cochlear implant</td>
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<tr>
<td>dB</td>
<td>DeciBel</td>
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<tr>
<td>ENT</td>
<td>Ear, nose and throat</td>
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<td>HADS</td>
<td>Hospital Anxiety and Depression Scale</td>
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<td>HL</td>
<td>Hearing level</td>
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<td>ISI</td>
<td>Insomnia Severity Index</td>
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<tr>
<td>ISO</td>
<td>International Organization for Standardization</td>
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<td>ISSNHL</td>
<td>Idiopathic Sensorineural Sudden Hearing Loss</td>
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<tr>
<td>kHz</td>
<td>kiloHertz</td>
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<tr>
<td>MD</td>
<td>Meniér’s disease</td>
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<td>MRI</td>
<td>Magnetic resonance imaging</td>
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<td>NIHL</td>
<td>Noise induced hearing loss</td>
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<td>PTA</td>
<td>Pure tone average</td>
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<td>QOLI</td>
<td>Quality of Life Inventory</td>
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<td>SD</td>
<td>Standard deviation</td>
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<td>SNHL</td>
<td>Sensorineural hearing loss</td>
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<td>SOAE</td>
<td>Spontaneous Otoacoustic Emission</td>
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<td>THI</td>
<td>Tinnitus Handicap Inventory</td>
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<td>THQ</td>
<td>Tinnitus Handicap Questionnaire</td>
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<td>VS</td>
<td>Vestibular Schwannoma</td>
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<td>WHO</td>
<td>World Health Organization</td>
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INTRODUCTION

Tinnitus is a common condition in Western populations (Axelsson & Ringdahl, 1989; Rosenhall & Karlsson, 1991; Sindhusake et al., 2003). The verb tinnire is derived from Latin and means to buzz, hum, jingle, or ring. The World Health Organization (WHO) has warned that hearing-related diseases, including tinnitus, will be one of the ten most prevalent disease categories in the near future (WHO, 2004). Tinnitus is an auditory symptom and is often associated with hearing loss. Tinnitus can be described in many different ways, such as the presence of constant or pulsating, high- or low- frequency sounds, or sometimes as more complicated sounds. The sound level can vary from barely noticeable to very disturbing, and this perception also varies among individuals and within an individual over time. Tinnitus most commonly occurs bilaterally (Andersson et al., 2005).

Sensorineural hearing loss (SNHL) refers to hearing loss that results from damage to the cochlea or the auditory nerve. SNHL occurs most commonly as a result of normal aging, a reduction of cochlear hair cells, or damage to the auditory nerve. Other than cochlear implantation (CI), surgical treatment is not possible for patients with SNHL; therefore, a hearing aid should be recommended for these patients.

Although hearing loss is not life-threatening, the resulting loss of speech recognition can have a significant impact on patients’ quality of life (Dalton et al., 2003). The same argument could also be made for patients who suffer from tinnitus (Corcetti et al., 2009).

BACKGROUND

Anatomy and physiology of the ear

The hearing organ is divided into two parts: the peripheral (the ear) and central (the brain) parts. The ear has three components, namely the outer, middle and inner ear (Figure 1). The outer ear consists of the pinna and ear canal; the pinna captures sounds, and the canal leads sounds toward the middle ear. At the end of the outer ear canal is the tympanic membrane, which separates the ear canal from the middle ear. The adult human ear canal extends from the pinna to the tympanic membrane and is approximately 35 mm in length and 5 to 10 mm in diameter.

The ear canal has an S-shape and is divided into fibrocartilaginous and bony parts. The ear canal forms a resonance channel that amplifies the sound pressure up to 15-25 dB at frequencies between 2 and 5 kHz. The tympanic membrane is a thin (0.1 mm), cone-shaped membrane that separates the external ear from the middle ear and is divided into the pars flaccida and the pars tensa. The pars tensa has a central fibrous layer (lamina propria), while the pars flaccida is slightly thinner. The middle ear consists of an air-filled cavity that contains the ossicular chain; the middle ear is externally bound by the tympanic membrane and faces the inner ear on the other side.
The eustachian tube links the air-filled cavity of the middle ear to the nasal part of the pharynx, and its task is to balance the barometric pressure in the middle ear. Under normal circumstances, the auditory tube is closed, but it can open to let a small amount of air through to prevent damage caused by differences in the pressure between the middle ear and the atmosphere.

The ossicular chain consists of three interconnected bones: the malleus, incus and stapes. The ossicular chain is attached to one side of the tympanic membrane by the malleus, and it inserts into the oval window of the inner ear by the footplate of the stapes. When a sound wave hits the tympanic membrane, it propagates through the ossicular chain and into the oval window of the inner ear. There are two muscles in the middle ear, namely the stapedius and tensor tympani, which insert into the stapes and malleus, respectively.

The inner ear is composed of two separately functioning systems, the cochlea and the vestibular apparatus. The cochlea is an approximately 30-mm-long coiled tube located within the petrous bone and is divided by membranes into three chambers: the scala vestibuli, scala tympani and scala media (Figure 2). The two outer chambers (the scala vestibuli and scala tympani) are filled with perilymph. The scala media is separated from the scala vestibuli by the Reissner's membrane and from the scala tympani by the basilar membrane. The scala media is filled with potassium-rich endolymph, while the scala vestibuli and scala tympani are filled with sodium-rich perilymph. The perilymph and endolymph are clear solutions and contain both electrolytes and proteins.
The organ of Corti rests on the basilar membrane and contains sensory cells arranged in one row of approximately 3,500 inner hair cells and three parallel rows of approximately 12,000 outer hair cells (Figure 3). Both inner hair cells and outer hair cells lie on the basilar membrane and are covered by the tectorial membrane, which is a gel-like structure containing mostly water. The basilar membrane is located above the sulcus spiralis internus and the spiral organ of Corti and extends along the longitudinal length of the cochlea parallel to the basilar membrane (BM). The tectorial membrane is divided into three zones: the limbal, middle and marginal zones. The highest frequencies that a human can perceive are detected by the basal parts of the organ of Corti, and other frequencies that can be detected gradually decrease toward the apical parts.
Hair cells are the sensory receptors in the auditory system. When the basilar membrane vibrates due to a travelling wave, the vibration is transferred by the hair cells to the auditory nerve; in this process, the outer hair cells serve as amplifiers. If the sound level is low, a mechanical amplifying motion takes place in the tectorial membrane that increases the stimulation of the inner hair cells. The inner hair cells transform the vibration into the fluids of the cochlea, where it is then transformed into an electrical signal (Müller, 2008). 

The cochlear nerve contains a total of 30,000 afferent nerve fibers (Spoendlin & Schrott, 1989). The cell bodies of these fibers are found in the spiral ganglion. The afferent fibers that carry sound information to the brain mostly contact the inner hair cells, while the efferent fibers that carry information back from the brain to the hair cells mostly contact the outer ear cells. The majority of the bodies of the efferent fibers are located in the superior olivary complex of the brainstem. The cochlear nerve leaves the cochlea through the internal auditory canal and enters the brainstem.

Posterior to the cochlea is the vestibular system, which is located in the bony and membranous labyrinth. The main components of this system are the utricle, saccule and semicircular canals. The labyrinth is filled with endolymph, and the space between these components is filled with perilymph (Kirikae et al., 1969).

The labyrinth artery is the sole blood vessel that supplies the inner ear. The artery divides into the cochlear artery and the anterior vestibular artery; the first part further divides into the main cochlear artery and the vestibulocochlear artery (Kirikae et al., 1969).

The central auditory nervous system (CANS)

The central auditory system involves all auditory structures from beyond the cochlear nerve to the primary auditory cortex in the brain, beginning with the cochlear nucleus complex in the brainstem (Figure 4).

From the cochlear nucleus, the majority of axons cross the midline to the lateral superior olivary complex. From here, some fibers follow the lateral lemniscus to the inferior colliculus, while some fibers project to the central side, as well as to the cerebellum and superior colliculus. From the lateral lemniscus, axons project to the medial geniculate body in the thalamus, where most fibers terminate in the primary auditory cortex, as well as in nonprimary auditory areas, association areas, the basal ganglia and the amygdala (Amunts et al., 2005).

The neural signals are transferred from the cochlea to the spiral ganglion. Axons from the ganglion cells are bundled together to form the auditory nerve (the eighth cranial nerve).
The ability to recognize and localize sound is dependent on processes and neural networks distributed throughout both hemispheres (Clarke et al., 2002). The recognition of environmental sounds seems to involve bilateral regions in the temporal and prefrontal areas (Maeder et al., 2001), and sound localization seems to activate a large cortical area, especially the temporal, parietal and prefrontal cortices (Maeder et al., 2001).

Hearing impairment

Tinnitus patients often report hearing loss. This loss is usually a sensorineural impairment (cochlear or retrocochlear) encompassing the entire spectrum of ear diseases, such as exposure to noise, the use of ototoxic drugs and the slow process of hearing impairment in presbycusis (Sindhusake et al., 2003; Sindhusake et al., 2004). The pathophysiological basis of the tinnitus that often coexists with sensorineural hearing loss will be discussed here. Inner ear diseases can lead to hearing loss and may also result in tinnitus (Hoffman & Reed, 2004). However, not everyone suffering from hearing loss will develop tinnitus, and not everyone who suffers from tinnitus has a hearing impairment (Kim et al., 2010). Findings from a recent study showed that 7.4 to 20% of tinnitus patients did not exhibit hearing loss at any frequency of conventional pure tone audiometry (Shim et al., 2009). A recent study examined the neuroanatomical alterations associated with hearing loss and tinnitus in three patient groups: those with both hearing loss and tinnitus, those with hearing loss without tinnitus and normal-hearing controls without tinnitus (Husain et al., 2010). The findings of that study showed that individuals with only hearing loss had significantly less gray matter in the anterior cingulate, superior gyri and medial frontal gyri compared with those with both hearing loss and tinnitus. In addition, the authors found a further reduction in the superior temporal gyrus in the hearing loss group compared with the tinnitus group. The results of an investigation of the effects of hearing loss alone showed that the gray matter loss in the superior and medial frontal gyri in patients with hearing loss was similar to that in the normal-hearing controls. A loss in
fractional anisotropy values in the right superior and inferior longitudinal fasciculi,
corticospinal tract, inferior fronto-occipital tract, superior occipital fasciculus, and anterior
thalamic radiation in the hearing loss group compared with normal-hearing patients was also
shown in this study (Husain et al., 2011). Future research could explain why different tinnitus
treatments are beneficial for some patients but have no effect on others.

A relationship between the development of a tinnitus perception and the neural plasticity
of the central auditory system (including the auditory cortex) often exists (Bauer et al., 2008;
Engineer et al., 2011). According to Jastreboff and Hazell (2004), this imbalance of neural
activity that can cause tinnitus-related changes affects type I and type II fibers of the auditory
nerve (Jastreboff & Hazell, 2004). The result can be a bursting activity at the dorsal cochlear
nuclei level in the brainstem that could lead to a disturbance of the afferent input to the
cochlear nerve. After further amplification within the auditory pathways, this process may be
perceived as tinnitus.

However, not every individual subjected to the same process subsequently suffers from
tinnitus. Generally, the answer to this phenomenon is not found in the psychophysical
parameters of tinnitus (Andersson et al., 2005). Loud tinnitus or tinnitus sounds at a certain
frequency could lead to increased distress, and patients who experience more complex sounds
report greater problems (Dineen et al., 1997). Another possible explanation for this result
could be that pre-existing psychological characteristics affect the way in which a patient
reacts to tinnitus (Andersson et al., 2005).

For a general understanding of the association between tinnitus and hearing loss, it is
important to discuss a number of otological pathologies to comprehend the various associated
symptoms.

The main subtypes of lesions associated with hearing impairment in humans, based on the
location of the lesion, are central and peripheral lesions, the latter of which are divided into
sensorineural and conductive lesions.

Conductive hearing loss is caused by a disease or damage to the eardrum or middle ear
and usually results in a reduced sensitivity over the entire frequency range. The signal
transmission from the middle ear to the inner ear decreases independently of the sound
pressure level of the stimulus. Conductive hearing loss can be detected by audiometry, where
an air-bone gap above 10 dB can indicate that the transmission of sound between the middle
ear and inner ear does not function optimally.

Diseases or damage to hair cells cause a reduction in the sensory function. Sensorineural
hearing loss (SNHL) can also be detected by an audiometry reading that indicates no gap
between the air and bone thresholds, i.e., the air-bone conduction is equal to the bone
conduction. This result means that the signal transmission from the middle ear to the inner ear
functions well, but some other obstacle prevents the sounds from being perceived by the
brain. SNHL is the most common type of hearing impairment.

Hearing impairment can sometimes be due to a combination of conductive and
sensorineural hearing loss, termed mixed hearing loss, and can sometimes be due to damage
to the central pathways, termed central hearing loss.
Sensorineural hearing loss

Sensorineural hearing loss (SNHL) can be classified into several other subdiagnoses that are discussed in this section. Presbycusis is a common type of sensorineural hearing loss caused by normal, biological changes in the cochlea and the degeneration of the spiral ganglion. Studies show that presbycusis affects approximately half of the population older than 75 years (Gates & Mills, 2005). The first and defining sign of presbycusis is a loss of threshold sensitivity in the high-frequency region of the hearing spectrum. Changes in this region can already begin in young adulthood but are usually first detected at 60 years if no other factors are involved. Over time, the threshold increasingly progresses to lower frequency areas (Schuknecht & Gacek, 1993). However, pure presbycusis is difficult to identify because this type of hearing loss is more often a combination of several factors, including genetics, life style and noise exposure factors (Christensen et al., 2001; Guimaraes et al., 2004).

Noise-induced hearing loss (NIHL) is currently a growing problem worldwide. Intense noise exposure sometimes leads to a temporary threshold shift in the cochlea but can also lead to permanent hearing loss that may be accompanied by other auditory disorders, such as tinnitus and hyperacusis (Axelsson & Sandh, 1985). Noise exposure can cause changes throughout the entire auditory pathway and an imbalance of the excitatory and inhibitory transmitter systems (Milbrandt et al., 2000; Dong et al., 2009). NIHL is generally bilateral and symmetric and affects higher frequencies first, followed by lower frequencies.

Hearing loss induced by ototoxic drugs can be temporary or permanent. Drugs such as aminoglycoside antibiotics and cisplatin can cause permanent threshold changes (Rybak & Whitworth, 2005). These drugs can lead to high-frequency hearing loss and are associated with a loss of outer hair cells in the cochlea.

Menière’s disease (MD) is a disorder of the inner ear, characterized by repeated spontaneous and episodic vertigo over time, fluctuating hearing loss and (sometimes) tinnitus. The cause is still unknown, but it is believed that endolymphatic hydrops is a pathophysiological condition closely associated with the disease (Ikeda & Sando, 1984). Several studies have suggested that the symptoms of MD originate from a change in the volume/pressure relationship of the endolymph. It is unknown whether the expansion of the hydrops is the cause of the symptoms or simply a side effect of the disorder (Paparella & Djallilian, 2002; Minor et al., 2004). The mechanism by which hydrops produces symptoms is unknown. The increased volume of endolymph could be due to fluid overproduction or decreased resorption. Furthermore, a rupture of the membranous labyrinth often occurs in Menière’s disease from the increased pressure within the scala media.

Idiopathic Sensorineural Sudden Hearing Loss (ISSNHL) is described as a symptom rather than a disease (Hallberg, 1956) and can be accompanied by tinnitus and/or vertigo. There are different theories regarding ISSNHL; some researchers state that it can be a result of local autoimmune processes that affect the cochlea (Campbell & Klemens, 2000), while others claim that this disease may be a consequence of infection or a vascular disorder (Kellerhals, 1972; Wilson et al., 1983; Hultcrantz et al., 1994). There are different types of treatments, including corticosteroids, that are based on the immune theory (Kanzaki et al., 1988; Russolo & Bianchi, 1997; Nosrat-Zarenoe & Hultcrantz, 2012).
**Background**

*Cochlear Otosclerosis* is an uncommon disease and usually presents in young patients. This disease often occurs between 30 and 50 years of age and is known to worsen during pregnancy. The stiffening of osseous bone causes a mixed hearing loss (sensorineural and conductive hearing loss) that is occasionally combined with tinnitus (Youssef et al., 1998; Hayashi et al., 2006).

Retrocochlear lesions are located beyond the cochlea on the vestibulocochlear nerve or in one of the auditory areas of the brain. *Retrocochlear hearing loss*, or neural hearing loss, is the result of damage to structures beyond the cochlea or neural systems occurring at the level of the auditory nerve or the auditory cortex, which causes degeneration of the hearing nerves. Alternatively, retrocochlear hearing loss can result from the inability of the hearing nerves themselves to convey neurochemical information through the central auditory pathways (Moore, 2008). A rather common cause of retrocochlear hearing loss is the growth of a benign tumor (*vestibular schwannoma*) that presses on the auditory nerve.

The types of retrocochlear hearing loss are divided into two groups: *central and vestibular nerve diseases* (Moore, 2008). Auditory diseases (*central*) are the disorders of hearing or auditory perception resulting from diseases of the central auditory pathways or auditory-associated cortical areas, such as cortical deafness. Above the level of the pons, bilateral lesions are usually required to produce auditory dysfunction. *Vestibulocochlear nerve* diseases are the diseases that damage the vestibular and/or cochlea nerves (*vestibular schwannoma*).

**Audiological examinations**

Audiological diagnoses are based on results from clinical examinations. The investigation of suspected hearing loss usually starts with hearing testing performed by the primary care giver. There are several methods to manually examine a patient, including Weber’s and Rinne's tests, both of which utilize a tuning fork, as well as conversation and whisper tests. These tests can elucidate the side and approximate degree of hearing impairment and estimate whether the hearing loss is likely due to a conduction error or a sensorineural hearing loss. After this examination, the patient is often referred to an ENT or audiology clinic for further testing. The most common method for detecting hearing impairment in ENT clinics is pure tone audiometry.

*Objective* hearing tests can sometimes be necessary if a patient is unable to participate, as these tests do not require active cooperation from the participant. These tests can be performed to gain insight into the potential causes of the abnormality and include electrophysiological testing, otoacoustic emission (OAE) measurement and tympanometry. The first two tests are discussed later in this section. Tympanometry examines the mobility of the tympanic membrane and conduction bones in the middle ear by generating variations in air pressure in the ear canal. This test measures the sound energy transmission through the middle ear, which reflects the pressure relative to the ear canal.

Pure-tone audiometry is a widely used clinical measurement method that can reveal the state of the hearing threshold levels and indicate the location of the probable cause. There are further examinations, such as auditory brainstem response (ABR) measurement and magnetic resonance imaging (MRI) that can rule out a retrocochlear cause.
**Audiometry**

Pure-tone audiometry using an audiometer is a standardized clinical method that measures a patient’s auditory sensitivity and can detect hearing thresholds over a range of frequencies (usually ranging from 125 Hz to 8 kHz). The procedure involves active participation of the patient because the measurement is based on the patient’s response to sound stimulation.

Requirements of the equipment used for pure-tone audiometry are specified in IEC 60645-1 (IEC, 2001). The calibration of the audiometer is also standardized according to ISO 389 (ISO, 1994).

A patient’s hearing threshold, measured by an audiometer, is quantified in dB hearing levels (HLs), which are defined from a standardized average hearing threshold for otologically normal subjects between 18 and 30 years old (ISO, 1994).

Hearing threshold measurements are performed by presenting an audible stimulus to the patient using earphones or a bone vibrator; this procedure is standardized according to ISO-8253-1 (ISO 1989). When a response to the stimuli is received, the stimuli level decreases by 20 dB until the patient does not respond. Then, the level is increased from an inaudible level in 5-dB steps. The threshold is determined when three out of a maximum of five levels are detected. The frequencies range from 125 Hz to 8 kHz. The result of the hearing threshold level test is described in terms of the dB HL (ISO, 1994).

**Otoacoustic Emissions (OAEs)**

Otoacoustic emissions are the measurable sounds in the ear canal. The activity of outer hair cells creates a wave motion and an energy loss toward the basal part of the cochlea that spread through the middle ear (Kemp, 2002). OAEs can be spontaneous or can occur in response to sound input to the ear (Andersson et al., 2005). There are two types of OAEs: transient evoked otoacoustic emissions (TEOAEs) and spontaneous otoacoustic emissions (SOAEs). The measurement of OAEs requires an earpiece that contains a microphone to record the waves and a speaker for stimulation.

**Auditory Brainstem Response (ABR)**

ABR analysis is performed to investigate the functioning of the peripheral auditory nerve and the auditory brainstem pathways (George et al., 2008; Cahill et al., 2008). ABR analysis can determine whether the hearing loss of a patient is caused by damage to the cochlear nerve or whether it more likely originates in the inner ear. Pure-tone audiometry and ABR analysis together can be used to detect the existence of a Vestibular Schwannoma (VS). This combination of measurements has previously been used in the diagnosis of patients with hearing disorders, cranial tumors, and vascular diseases (Zimmerman, 1994), (Kon et al., 2000; Kaga et al., 2004; Buckard et al., 2006).

The ABR is obtained by measuring the electrical response in the brainstem nuclei while stimulating the hearing organ with clicking sounds (Gorga et al., 1988). A great advantage of ABR is that the patient does not need to participate during the measurement, which makes it possible to measure the hearing level of, for example, neonatal babies and patients with dementia. (Cone-Wesson & Ramirez, 1997). Selters and Brackmann described abnormal ABR findings in 94% of a group of 46 patients with tumors of cranial nerve eight (Selters & Brackmann, 1977). In large extracanalicular tumors (greater than 1 cm in size), ABR analysis
Background

ABR analysis has traditionally been used to measure hearing thresholds or to detect hearing loss. Some recent studies show that thresholds can be improved after noise exposure even in the case of damaged auditory nerve synapses and reduced ABR wave I amplitudes (Kujawa & Liberman, 2009), which may be factors associated with the development of tinnitus. For ABR analysis or psychophysiological tests, such as pure tone audiometry, to indicate a retrocochlear lesion that could be a tumor, the tumor has to exert some effect (most commonly thought to be physical pressure) on the neurological structures involved (Fortnum et al., 2009).

Thus, changes in the ABR can be used as an objective measurement of tinnitus. Additionally, ABR analysis could expose areas of the auditory brainstem that are involved in tinnitus pathology (Kujawa & Liberman, 2009). Given the reduction in cost and improvements in the quality of MR imaging, ABR analysis should no longer be considered appropriate as the primary test used to screen for vestibular schwannoma (Fortnum et al., 2009; SBU, 2010).

Magnetic Resonance Imaging (MRI)

It is very important to correctly identify SNHL etiologies, including neoplastic lesions (vestibular schwannomas or cerebellopontine angle (CPA) tumors), multiple sclerosis and stroke. The early use of MRI scanning for the diagnosis of Vestibular Schwannoma (VS) showed that ABR testing missed tumors smaller than 2 cm in up to 9% of cases (Gordon & Cohen, 1995; Chandrasekhar et al., 1995).

MRI is the single recommended preoperative test for the diagnosis of tumors as small as 2 mm (Stack et al., 1988; Cueva, 2004; Fortnum et al., 2009). The latest recommendations suggest the removal of ABR analysis as a screening test in patients with asymmetric SNHL or if a tumor is suspected on cranial nerve VIII; furthermore, the adoption of a completely focused MRI protocol as the primary screening test for finding tumors, has been recommended (Cueva, 2004; SBU, 2010).

Tinnitus

A historical description

Tinnitus has likely troubled humanity since the dawn of civilization. The first written account of medical treatment for tinnitus came from the Egyptians and Mesopotamians (Stephens, 1984). In ancient Greece and Rome, poetry was written that described tinnitus as a symptom of passionate love, jealousy and telepathy (Stephens, 1984).

In Stephens’ review of the literature from the early nineteenth century (Stephens, 1984), he highlighted two authors: Jean Marie Gaspard Itard (1775-1838) and John Harrison Curtis (1778-1860). Itard’s main publication was 'Traite des Maladies de l'oreille' (Itard, 1821), the second volume of which included a chapter on tinnitus and its treatment. Itard recognized that tinnitus was often associated with hearing loss. He defined a test involving the placement of
pressure on the carotid artery to differentiate between tinnitus-induced hearing loss and tinnitus secondary to hearing loss.

Curtis (1778-1860) studied other tests involving setons, blisters and bleeding. However, Curtis did recognize the psychological aspects of tinnitus and often supported psychological cures involving rest, spa treatment and other similar remedies (Curtis, 1831). Furthermore, he recognized the importance of early treatment of tinnitus and believed that a long-term psychological consequence of tinnitus could be a change of the sound into auditory hallucinations.

Several authors (e.g., Vernon, 1981; Hazell, 1979) have attributed the following statement on masking, the earliest known statement on this feature, to Hippocrates: “Why is it that buzzing in the ears ceases if one makes a sound? Is it because a greater sound drives out the less?” In fact, this statement could have been the foundation for one of the most well-known tinnitus treatment models, namely Tinnitus Retraining Therapy (TRT).

Epidemiology

Tinnitus is a common complaint in the global population (Andersson et al., 2005). According to different studies with different age groups, the approximate prevalence of tinnitus is between 10 and 15% (Axelsson & Ringdahl, 1989; Rosenhall & Karlsson, 1991), (Cooper Jr, 1994; Scott & Lindberg, 2000; Andersson et al., 2002; Shargorodsky et al., 2010). Another common observation is that the prevalence of tinnitus increases with age (Andersson et al., 2005).

Gender differences regarding tinnitus have been observed in many studies (Dineen et al., 1997; Shargorodsky et al., 2010) specifically, women are more likely to report having tinnitus than men. Accordingly, there are several studies on tinnitus that show a slightly higher prevalence in females (Leske, 1981; Coles, 1984; Nondahl et al., 2007). However, the prevalence was greater in females below the age of 40 years, while tinnitus was more common in males between 40 and 70 years of age in other studies (Axelsson, 1999). Men have traditionally been more exposed to noise in the form of firecrackers, firearms (military), and noisy work environments. However, women are more severely annoyed by their tinnitus (Axelsson & Ringdahl, 1989; Stouffer & Tyler, 1990).

Tinnitus can be divided into two categories. Objective tinnitus can be recorded objectively by a microphone or can be heard by another listener (Lustige, 2010). The sound can come from, for example, the carotid artery, auditory tube or temporomandibular joint (Noell & Meyerhoff, 2003; Crummer & Hassan, 2004).

The perceived localization of the patient’s tinnitus can potentially be of diagnostic significance, especially because unilateral tinnitus may be a symptom of an underlying vestibular schwannoma. In some previous studies, tinnitus was found to affect the left ear more commonly than the right ear, especially in male patients (Meikle et al., 1984; Erlandsson et al., 1992). A possible explanation for the higher incidence of left-sided tinnitus has yet to be proposed. Furthermore, there is no evidence that left-sided tinnitus is more annoying than right-sided tinnitus (Andersson et al., 2005).

Tinnitus is often accompanied by some degree of hearing loss (Irvine et al., 2001; Sindhusake et al., 2003). This loss is usually a sensorineural impairment, either cochlear or retrocochlear, and can be due to aging, noise exposure or ototoxic drugs (Chung et al., 1984;
Background

However, tinnitus may also be present in individuals with normal hearing (Stouffer & Tyler, 1990; Schaette & McAlpine, 2011), but the difference in the annoyance level between the groups is unclear. Symptoms may originate in several different places in the auditory system and may have various causes, such as conductive hearing loss (e.g., otosclerosis and infections in the middle ear) or problems in the cochlea (e.g., Menière’s disease, sudden sensorineural hearing loss, and presbycusis) (Billue, 1998). Reports have suggested that patients with normal hearing, as assessed by various clinical tests, may have cochlear damage or hearing loss at frequencies above 8 kHz (Weisz et al., 2005). The primary lesion in most cases of hearing loss resides in the hair cells and/or spiral ganglion neurons. Studies that investigated the effects of noise exposure or ototoxic drugs have shown that damage to the inner or outer cochlear hair cells increases the auditory nerve fiber threshold (Dallos & Harris, 1978; Schmiedt & Zwislocki, 1980; Liberman, 1984; Devarajan et al, 2012).

The loudness of tinnitus sounds fluctuates in the majority of individuals with tinnitus (Erlandsson et al., 1992; Devarajan et al., 2012). The volume can be altered by exposure to loud sounds, nerve tension, increased blood pressure, lack of energy and some chemical substances, such as drugs, alcohol, caffeine and tobacco. However, relaxation and good physical fitness can make the tinnitus less disturbing (Stouffer et al., 1991).

The current models of tinnitus origination in humans argue that damage to hair cells can encourage an imbalance in lateral inhibition on other neuronal levels and can cause central plasticity (Eggermont, 2003).

Lateral inhibition occurs when the activity of an excited neuron reduces the activity of the nearby neurons in the same area. The reduced spontaneous activity of nerve fibers with different characteristic frequencies in the hearing loss range could result in a reduction of lateral inhibition at more central levels. This reduced lateral inhibition of neurons induces hypersensitivity and hyperactivity in these neurons (Eggermont, 2003), which are highly likely to be interpreted as a sound stimulation (Eggermont & Roberts, 2004).

Theories

Non-cochlear models

The neurophysiological theory of tinnitus was first presented by Jastreboff et al. (1996). This theory involves auditory perception, emotional and reactive systems and a combination of peripheral and central dysfunction (Attias et al., 2002). Jastreboff et al. (1996) suggested that tinnitus sound interpretation involved the limbic system and the autonomous nervous system (Jastreboff et al., 1996). The tinnitus sound is interpreted in a negative way, making the individual aware of something abnormal; this awareness allows the sound to be perceived as a distressing symptom. Several researchers have described that the interpretation of the tinnitus sound could be associated with an adverse episode in the individual’s life (Jastreboff et al., 1996; Jastreboff & Jastreboff, 2000; Henry & Wilson, 2001).

Another theory suggests that tinnitus occurs from the adoption of a temporal pattern in the auditory nerve activity (Eggermont & Roberts, 2004). Calcium is very important for the cochlea and its hair cells (Zenner & Ernst, 1993), and increases in the amount of calcium in the hair cells could lead to an amplified signalling to the brain. If this signalling occurs in a
Background

dysfunctional cochlea, it would lead to increased neurotransmitter release from inner hair cells and increased activity in the auditory nerve fibers in the form of cascade signalling (burst firings). The synchronization of activity in the small nerve fibers could cause the perception of the tinnitus sound (Baguley, 2002).

Cochlear models

A normal cochlea can produce low-intensity tones without acoustic stimulation (Gold, 1948). Tinnitus in individuals with normal hearing is often associated with a varying degree of cochlear dysfunction (Jakes et al., 1986; Satar et al., 2003; Shim et al., 2009). Some researchers believed that tinnitus could be measured objectively by measuring spontaneous otoacoustic emissions (SOAEs), but studies have shown that 38-60% of individuals with normal hearing also could have these measurable emissions (Penner, 1990; Kim et al., 2010).

The tectorial membrane can be clamped toward the inner hair cell’s cilium due to toxic drugs or loud noises. This change can result in a depolarization of the inner hair cells (Jastreboff et al., 1996; Baguley, 2002; Ricci, 2003). The frequency of the tinnitus sound in these individuals is often matched to the frequency of their hearing loss (Eggermont, 2003). Damaged outer hair cells on the basilar membrane may sometimes contribute to the onset of tinnitus (LePage, 1987). The normal function of outer hair cells is to enhance the sound before it is received by the inner hair cells. Outer hair cells also check the sensitivity of the inner hair cells’ operating level by assessing the difference between the sound transmitted and the sound that the brain normally interprets as no sound (Baguley, 2002; Ricci, 2003). When the outer hair cells lose their mobility, they also lose the ability to control the normal function of the inner hair cells (Ricci, 2003). This loss of function modifies the normal input such that what is normally interpreted as a normal state is now perceived as tinnitus (Baguley, 2002).

In the auditory cortex, all frequencies are tonotopically mapped to show the coding of the different frequencies at the basilar membrane. The tonotopical mapping reorganizes after an injury (Eggermont & Roberts, 2004); the normal function of the neurons in the cortex is modified, which implies that these neurons do not respond to their own frequencies or to the frequencies at the non-affected area (Eggermont & Roberts, 2004).

Phantom perception

Tinnitus is not the only phantom perception in humans and is similar to phantom pain (Goodhill, 1950). Cortical reorganization, such as occurs in the case of phantom pain, occurs in the cortical auditory areas after peripheral changes (Baguley, 2002; Weisz et al., 2007). Damages to specific parts of the hair cells can lead to activity reduction in the cortical area at corresponding frequencies (Baguley, 2002). One consequence of this reorganization is that a disproportionate number of neurons become sensitive to frequencies in the upper and lower limits of the hearing loss (Dietrich et al., 2001). Spontaneous activity in these areas can be perceived as tinnitus sound (Baguley, 2002).

Measurement methods for tinnitus

By developing and improving the procedures for testing hearing ability, it has been easier to more precisely determine hearing thresholds. There have been many attempts to measure the tinnitus sound, loudness and pitch (Penner & Klafter, 1992; Mitchell et al 1993). Because
Background

Tinnitus is often subjectively perceived, a direct measurement of the degree of tinnitus severity is often obtained through self-report questionnaires. THI is among the most validated and useful method to measure the impact of tinnitus on patients life (Newman et al., 1996).

Because tinnitus can have an impact on different aspects of a patient’s life, secondary questionnaires that are related to the patient’s sleep, anxiety, depression and other health problems are commonly administered. Among those, the Hospital Anxiety and Depression Scale (HADS) (Zigmond & Snaith, 1983), Quality of Life Inventory (QOLI) (Frisch et al., 1992) and Insomnia Severity Index (ISI) (Bastien et al., 2001) are the most commonly used in tinnitus research. The HADS and QOLI measure patients’ psychological mental health and provide a profile of patients’ life situations, while the ISI describes the patients’ sleeping habits. These questionnaires enable a better understanding of the patients’ life situations, which can significantly impact the rehabilitation process.

Treatment models

Despite the existence of a large variety of treatment models, there is no permanent cure for tinnitus. Improving the circulation of the cochlea that may have been altered following certain types of insult or trauma can help in the recovery process (Hultcrantz, 1988); however, the results from another study showed that the vasodilator effect does not alter tinnitus (Hulshof & Vermeij, 1987).

Different treatment options have been used in the management of tinnitus, including surgical, drug and psychological treatments. Surgery has been performed on patients when tinnitus is secondary to an underlying condition, such as otosclerosis or VS (Andersson et al., 2005). Because both depression and anxiety are frequently present in patients with tinnitus, psychoactive drugs may suppress the annoyance of tinnitus.

Masking is another treatment that covers up/masks the tinnitus sound by providing the patient with an external, manufactured sound (Jasterboff & Hazell, 2004). However, the generators that produce the sound can only offer a limited range of different sounds, which do not satisfy the majority of the patients.

The list of alternative therapies (e.g., acupuncture, music therapy, various herbal therapies, and relaxation) is long and demonstrates the strong need of patients who suffer from tinnitus to find relief. Jastreboff and Hazell (2004) emphasize the importance of counselling and its effect on tinnitus patients (Jastreboff & Hazell, 2004). Listening and confirming patients’ complaints about their complex problem and providing adequate advice that could reduce the tinnitus annoyance constitute a very appropriate method that can be used by clinicians to assist patients. However, it is generally difficult to differentiate the counselling effects of the alternative medicine approaches from the effects of the actual treatment administered to the patients.

In most cases, an individualized treatment strategy can provide the best results (Jastreboff et al., 1996; Noell, 2003; Kaldo & Andersson, 2004; Zetterqvist-Westin et al., 2011). Worldwide, two of the most commonly used treatment modalities are tinnitus retraining therapy (TRT) and cognitive behavior therapy (CBT). TRT consists of two parts, namely directive counselling and sound enrichment, the latter of which is accomplished by a white noise generator. The importance of the use of a sound generator in TRT is not clearly
described. Thus, stimulations using every-day sounds have also been recommended. In this case, if the patient has a hearing impairment, hearing aids combined with an integrated sound generator are recommended. CBT is one of the more recent forms of psychotherapy and is characterized by a focus on how thoughts, behaviors and reactions affect each other. A successful treatment should eliminate the disturbance caused by the tinnitus and aid patients in accepting and dealing with their tinnitus. The purpose of hearing aid fitting in patients with both tinnitus and hearing loss is to reinforce sounds that patients have difficulty hearing due to their hearing loss and to provide external auditory stimuli that can mask the tinnitus. Hearing aids have become widespread treatment modalities and are currently offered in many clinics worldwide. Furthermore, hearing aid use in patients with both tinnitus and hearing loss has been recommended (Jastreboff & Hazell, 2004). Modern hearing aids with advanced programs can suppress background environmental sounds that can enhance tinnitus.

With an increasing number of treatment options for patients suffering from tinnitus, caregivers have been searching for further rehabilitation alternatives that may have a greater impact on patients’ sensitivity to their tinnitus; acceptance and commitment (ACT) therapy is one of these options. The goal of ACT is to increase the quality of life rather than to try and remove the annoyance or pain sensation.

In our ENT clinics, we use the Stepped Care approach. In this, the first step is that the patients see an audiologist with special training for counselling and diagnosing patients with tinnitus and hearing problems. Step number two is a multidisciplinary information meeting for those patients who did not feel they got enough help from the first step. As a final step, the patients who are not satisfied with step two are offered individual therapy that could include CBT, physiotherapy, counselling, physiotherapy etc. Thus, the resources of the clinic are used for the patients who need them the most.

Tinnitus Retraining Therapy (TRT)

The hypothesis associated with TRT is that two different processes of non-habituation create tinnitus perception and tinnitus annoyance. A combination of counselling and sound therapy is used in TRT. Sound therapy, which can be conducted with or without an instrument, provides sound at the pinnae using a device that generates white noise. The purpose of a noise generator is to provide a background sound. In TRT, hearing aids are also used for patients with hearing loss.

Initial evidence suggests that TRT can be an effective treatment for patients suffering from tinnitus (Henry et al., 2008). To implement TRT in clinical practice, the clinicians use a combination of sound therapy within a strict framework and educational counselling according to a detailed procedure (Jastreboff & Hazell, 2004). Many studies have discussed the use and evaluated the effectiveness of TRT. However, controlled trials with validated outcome measures are needed to support the efficacy of TRT (Phillips & McFerran, 2010). Phillips and McFerran (2010) referenced only one study with 123 participants that was published in two separate journals (Henry et al., 2006a), (Henry et al., 2006b). The results of that study suggested a considerable benefit of TRT in the treatment of tinnitus. However, Phillips and McFerran (2010) questioned the quality of that single study and suggested that the evidence was not robust enough for firm conclusions to be drawn.
Cognitive Behavior Therapy (CBT)

CBT is a treatment approach used to identify and modify behaviors, thoughts and cognitions that are disruptive for the individual (Balow, 2001); the CBT approach is based on a cognitive-behavioral model of tinnitus (Henry & Wilson, 2001; Andersson et al., 2002; Andersson et al., 2005). Patients with tinnitus have reported difficulties in concentration and have claimed that their tinnitus can steal all of their attention. Through CBT, clinicians can help patients accept their tinnitus and assist them in ignoring the sound and not giving it as much attention (Kaldo & Andersson, 2004). CBT can be conducted in small groups or individually and is usually provided over six to ten sessions that occur on a weekly basis (Kröner-Herwig et al., 1995; Andersson et al., 2005).

A new psychological approach in the field of tinnitus rehabilitation

Recently, a study suggested positive results of a new treatment technique called acceptance and commitment therapy (ACT) for patients with annoying tinnitus (Zetterqvist-Westin et al., 2011). This approach has been tested on other diseases and symptoms, such as chronic pain (Vowles & McCracken, 2008; Wicksell, et al., 2009), type-2 diabetes (Gregg et al., 2007) and epilepsy (Lundgren et al., 2006). Outcomes from these studies have shown promising results of ACT in these patients. In all of these trials, the outcomes were mediated in part by the suggested processes of the therapy (Lundgren et al., 2008; Vowles & McCracken, 2008; Wicksell et al., 2010).

Hearing Aid Fitting

For many years, hearing aid fitting has been a useful treatment for patients suffering from both tinnitus and hearing impairment (Searchfield et al., 2010). Amplification of sound by hearing aids can increase the level of neural activity, which can reduce the gap between the tinnitus stimuli and the background neural activity (Parra & Pearlmutter, 2007; Searchfield, 2008). The use of hearing aids can also indirectly help patients with both tinnitus and hearing impairment by reducing the negative effects of tinnitus annoyance, regardless of the severity of the hearing loss (Surr et al., 1985; Carmen & Uram, 2002).

Current hearing aid studies have verified the effects of the currently available technology and compared more sophisticated hearing aids with less sophisticated aids used in tinnitus management (Trotter & Donaldson, 2008; Searchfield et al., 2010). Patients who used hearing aids and combined this treatment with counselling obtained approximately twice the reduction in their tinnitus handicap than those who preferred only counselling (Aazh, et al 2009).

Despite the obvious benefits of using hearing aids, many patients with hearing loss do not consider hearing aids as a treatment option (Aazh et al., 2009).
AIMS

Study I
To describe a large cohort of patients with tinnitus and SNHL in Sweden.
To analyze the possible differences in examination methods and treatment models in different subgroups.

Study II
To evaluate the quality of life in patients with tinnitus and SNHL.
To investigate patients’ mental and physical health.
To measure the level of satisfaction concerning the care the patients obtained.
MATERIALS AND METHODS

Materials

Both studies were retrospective, descriptive studies based on data from patients who sought care for tinnitus and hearing loss at the two ENT clinics in Östergötland County, Sweden, from 2004 to 2007 and who received a diagnosis code.

Patients between 20-80 years of age with tinnitus and a PTA lower than 70 dB HL were included in the study. In Östergötland, patients with a PTA>70 dB HL can be candidates for cochlear implants (CIs); therefore, these patients were not included in this study. Because of their profound hearing loss, these patients have severe problems.

Patients were excluded from the analyses if they had a CI, middle ear disorders, or a hearing loss since birth/childhood. Multi-handicapped patients and those who did not speak fluent Swedish and required an interpreter at the ENT visit were also excluded.

The time period used in this study was chosen because the multidisciplinary team started in 2004 and remained a complete team until the spring of 2008. A nurse and a physiotherapist left the team at that time, which limited the ability of the team to offer patients a complete set of treatment options.

A medical record review of all patients (study I contained 1672 subjects) revealed that 714 patients were diagnosed with both tinnitus and SNHL between 2004 and 2007 and could be included in study II (Figure 5). Three questionnaires and a request to participate in this study were sent by mail to all 714 patients. The first dispatch resulted in 375 responses. A reminder was sent after 4 weeks to those whose answers were not received, which resulted in an additional 180 responses. Thus, a total of 555 (78%) patients responded, and of those, 426 (60%) submitted their answers to the questionnaires (Figure 5). The questionnaires were sent back by 129 (18%) patients who informed us that they did not want to participate in this study.

Figure 5. Study flowchart
**Materials and methods**

**Methods**

The hearing loss of patients was classified as unilateral hearing loss when one of the ears was within normal limits, i.e., the pure tone average (PTA) was $\leq 20$ dB HL, and the PTA of the other ear was $>20$ dB HL. Bilateral hearing loss was defined as either symmetric or asymmetric hearing loss in which the PTA for both ears was $>20$ dB HL. A hearing loss was classified as asymmetric if the difference between the PTA in both ears was larger than $15$ dB HL. All classifications were made during the first visit by the ENT doctors based on patients’ audiograms. The investigators completed a form for each patient that covered background information and audiograms obtained at the yearly check up. The background information contained data on each patient’s tinnitus, vertigo, hearing loss, diagnosis, further audiological examinations, tinnitus treatments, heredity for tinnitus, concomitant diseases and medication use.

**Outcome measures**

The Tinnitus Handicap Inventory (THI), EuroQoL 5D (EQ-5D) and a questionnaire about general health were mailed along with a request to participate in this study to all 714 patients with both tinnitus and SNHL. All assessments were sent by mail. Self-assessment instruments, such as the EuroQoL 5D (EQ-5D) and THI, were the basis of study II.

**EuroQoL (EQ-5D)**

Data on quality of life were collected using the EQ-5D, which is a standardized instrument for measuring health outcomes that provides a simple descriptive profile and a single index value for health status.

The EQ-5D contains five questions about mobility, self-care, usual activities, pain and depression on a three-degree scale in addition to a VAS scale that assesses current health status. The EQ-5D is used for a wide range of health conditions and treatments, such as population health surveys and the clinical and economic evaluation of health care. The EQ-5D has previously been used in Swedish studies on audiological rehabilitation (Persson et al., 2008).

**Tinnitus Handicap Inventory (THI)**

The Tinnitus Handicap Inventory (THI) is a tinnitus-specific, widespread, and validated questionnaire for quantifying tinnitus severity in patients’ daily lives (Newman et al 1998). Because of its wide use, the THI has been recommended in a consensus document to be used as an outcome measurement in clinical trials to allow comparability across studies (Langguth et al., 2007). This questionnaire has good psychometric characteristics (Newman et al., 1998) and is designed to evaluate behavioral and treatment outcomes in emotional and physical aspects of the patients’ health and lifestyles. The THI is a self-administered, 25-item questionnaire that is scored on a 3-point scale (No = 0, Sometimes = 2 and Yes = 4). The total THI score is the sum of the scores for the following three subscales: functional, emotional, and catastrophic. Based on the total THI score, tinnitus sufferers can be classified into four categories denoting handicap severity: no handicap (0-16), mild handicap (18-36), moderate handicap (38-56) or severe handicap (58-100).
Questionnaire about life quality

To assess the level at which the patients rank their own general health, another questionnaire was included that covered satisfaction with some aspects of their lives, such as their current physical health, physical activities, lifestyle, work and family situation, social cohesion, friendships, sleep, stress, personal development, interest and alcohol and tobacco consumption. This questionnaire is similar to the Quality of Life Inventory (QOLI). We did not use the QOLI to avoid having duplicate questions and to make it simple for patients to respond by shortening the response time. The answers ranged from 1 (representing a bad condition) to 10 (representing a very good condition). Three open questions were designed to determine whether the patients also sought care outside the ENT clinics, if the patients were willing to change their health situation, and, in that case, how they were willing to change. Participants were also asked to rate the care they received at our ENT clinics.
STATISTICAL METHODS

Statistical analyses in both papers were performed using Microsoft Office Excel, Windows 2003 and Statistica (Statsoft, Tulsa, OK, U.S.A.). The distribution of patients between groups with two or more possible states was evaluated using the Chi² test, and in the 2x2 case, the Yates correction was used. Measurement variables were compared between groups with a Student’s t-test.

In the case of paired measurements, we used McNemar’s test. Measurement variables were compared between the two groups with the Student’s t-test, and one-way ANOVA was used when comparing three or more groups.

The level of significance in both studies was set at p<0.05.

ETHICAL CONSIDERATIONS

The Eastern Regional Medical Research Ethic Committee located in Linköping, Sweden, approved both studies (registration number Dnr. M214-07). Participants in study II were given written information about the study by mail. All data were handled confidentially, and all analyses were conducted at the group level.
RESULTS

Study I

Patient characteristics

A medical record review of the entire group of 1672 patients with SNHL demonstrated that 1175 (70%) patients also had tinnitus (Figure 1, study I). Of the patients with both SNHL and tinnitus, 461 patients (39%) did not fulfill the inclusion criteria. The remaining group consisted of significantly more male patients (n=388; 54%) than female patients (n=326; 46%) (p=0.02) (Table 1, study I). In patients with unilateral tinnitus, the prevalence of tinnitus in the left ear was significantly higher (p<0.001). In addition, the PTA for the left ear was significantly higher than that for the right ear in male patients (p=0.01) but not in female patients (p=0.45). The results regarding the configuration of hearing loss revealed that 555 patients (78%) had symmetric and 159 (22%) had asymmetric hearing loss (Table 2, study I). High-frequency hearing loss was found to be more common (approximately 92%) in patients with symmetric hearing loss.

Examinations

Retrocochlear examinations were conducted in 372 patients, and MRI was the most common examination (Table 3, study I). There was a significant difference between patients with unilateral tinnitus and bilateral tinnitus regarding the use of the MRI examination (p=0.001). Patients with asymmetric hearing loss (61%) underwent more retrocochlear examinations than patients with symmetric hearing loss (50%, p=0.014).

Treatments

Of the 400 patients without hearing aids, 220 had unilateral tinnitus and 180 had bilateral tinnitus (Table 4, study I). There were significantly more patients with bilateral tinnitus (49%) who had hearing aids compared with patients with unilateral tinnitus (39%, p=0.02). A total of 219 patients had a PTA>20 dB and did not have a hearing aid. All patients were examined by an ENT doctor, and 135 (20%) of them met with an audiologist with tinnitus training for further treatment. Among those 135 patients, 83 participated in the group information session (Table 5, study I). Of all the patients, 105 participated in the comprehensive group information session on tinnitus, which is step 2 in the Stepped Care model. Based on the results of study I, it was estimated that 61% of the patients went from step 1 to step 2, whereas 71% continued from step 2 to step 3, with 43% of the patients in step 1 requiring the most resource-consuming treatments (Table 5, study I).

Study II

Patient characteristics

A total of 426 responses, which later formed the basis of study II, were received after two dispatches (Figure 1, study II). A comparison of the gender distribution between the participating, non-participating and non-responding groups showed that the non-participating group consisted of significantly more female patients than the other two groups (Chi2-test, p=0.007 and p=0.005, respectively) (Table 1, study II). The non-responding group had
Results

younger subjects compared with the other groups (post-hoc Tukey test, \( p=0.003 \) and \( p=0.001 \), respectively).

A total of 217 (51\%) patients in the participating group had bilateral tinnitus. In this group, there were 149 (69\%) patients with bilateral hearing loss and 68 (31\%) with unilateral hearing loss (Table 2, study II). The perceived tinnitus was lateralized to the same side as the hearing impairment (\( \chi^2=12.16, \ p<0.001 \)). There was no difference between patients with high-frequency hearing loss and other patients with regard to PTA and THI scores.

THI

Female patients had a significantly higher total THI score than male patients (\( p<0.05 \)) (Table 3, study II). For patients aged 20–40 years, the THI scores were higher compared with those of the other age groups, but this difference was not significant. A similar result was found in patients with bilateral tinnitus and patients with bilateral hearing aids. The patients aged 61–80 years had the lowest scores.

EQ-5D

Within each age group, a significant difference was seen when comparing the scores for “pain” and “depression” with the scores of other questions (\( p<0.05 \)) (Table 4, study II). The number of patients with self-care problems was low in all groups. There was no significant difference regarding the scores for EQ-5D, between the patients with and without hearing aids. Regarding the patients with various diagnoses, there were no significant differences among the groups, although patients with the diagnosis of Mb Meniéré had the lowest scores on the VAS scale.

Questions about patients’ general health

The youngest group (20–40 years old) had the lowest scores for the lifestyle question (\( p=0.015 \)) (Table 5, study II). Results for the sleep question showed that the patients in the middle-aged group had the lowest scores (ANOVA, \( p<0.05 \)). A post-hoc analysis showed that the middle age group had lower scores than the oldest group (Tukey test, \( p=0.03 \)). Patient age was correlated with stress levels (ANOVA, \( p<0.05 \)), with the youngest age group having the greatest amount of stress. However, none of the pairwise comparisons showed any significant differences.

Satisfaction statements

The patients were asked to rate their satisfaction regarding the care they received at the ENT clinics; 50 (12\%) patients did not answer at all, while the other 376 patients chose to respond (Table 6, study II). We used the PTA of the worst ear of the patient to describe the severity of the hearing impairment in the satisfied (group A) and dissatisfied (group B) patients. A significant difference was found between the groups, with group B having the lowest PTA (\( p<0.05 \)). It was more common for patients to not have hearing aids in group B (\( n=107, \ 61\% \)) than in group A (\( n=63, \ 42\% \)) (\( p=0.001 \)). Group A had a mean±SD THI score of 24.1±15.5, and group B had a significantly higher score of 33.0±16.3 (\( p<0.05 \)). Additionally, there was a significant difference between male and female patients regarding their satisfaction with the care they obtained and their THI scores, with the difference in the male group being more significant (\( p<0.005 \)) than that in the female group (\( p<0.05 \)).
DISCUSSION

The aims of this thesis were to analyze the possible differences in examination methods and treatment models in different subgroups and to evaluate the quality of life in patients with tinnitus and SNHL. The outcomes of this investigation show that the majority of patients who were dissatisfied with the care they obtained did not have hearing aids. The Stepped Care model could be used to lead patients to more individually adapted treatment and more accurate recourse in an ENT clinic. Additionally, we found significantly higher THI scores in female patients compared with male patients. The findings also showed a significant difference within each age group between the scores for “pain” and “depression” and those for other questions in the EQ-5D.

Tinnitus is common in patients with SNHL. Tinnitus affects approximately 10-15% of the population and is a common condition among older adults (Sindhusake et al., 2003; Sindhusake et al., 2004). Hoffman and Reed compared the prevalence of self-reported tinnitus from several large epidemiological studies (Hoffman & Reed, 2004) and found that, for patients aged 50 years and older, the estimated prevalence of tinnitus ranged from 7.6 to 20.1%. Our data from study I showed that the majority of patients (79%) were in the age group of 50 years and older. We found that 1175 (70%) patients also had tinnitus, which is consistent with previous studies that have reported a similar frequency (Axelsson & Ringdahl, 1989; Rosenhall & Karlsson, 1991; Cooper Jr., 1994; Scott & Lindberg, 2000; Andersson et al., 2002; Shargorodsky et al., 2010). We believe that our study included the majority of patients with both tinnitus and hearing impairment who sought treatment during the study period. These patients were willing to seek treatment at an ENT clinic, in contrast to patients who do not experience any problem with their tinnitus.

Method discussion

Our results showed that there was often a lack of information in the patients’ medical records, about vertigo, tinnitus, heredity for hearing loss and/or tinnitus, and information about the patients’ general health. Most of the information physicians obtain during a patient’s visit remains in physicians’ heads in "a constantly expanding and reinterpreted database" (Tanenbaum, 1994). This practice could obviously interfere with the development of an optimal care plan for the patients. We are unsure whether all of the patients received an adequate diagnosis given the very small sizes of some of the subgroups. For example, it is possible that patients who received a diagnosis of bilateral SNHL should have been classified as having presbycusis or noise-induced hearing loss. This classification could affect the outcome of rehabilitation; specifically, patients who may need further treatments/therapy/analysis may not be able to obtain these services due to incorrect classifications. We believe that the fact that some patients did not receive an adequate diagnosis further affected the outcome of our study. If all patients had received an accurate diagnosis, we would probably have seen a larger group in some cases, such as the presbycusis or ISSNHL group, which could have enabled us to better analyze some of our findings.

One of the limitations of our retrospective study was that we could only measure patients’ tinnitus experience long after the patients had received their diagnosis, which could explain
why the total THI scores indicated a rather mild degree of tinnitus annoyance in our cohort. Nevertheless, this finding is in agreement with other studies, e.g., (Gopinath et al., 2010), which suggests that the subjective distress associated with tinnitus can decrease over time and implies that some patients can habituate to tinnitus annoyance over time.

**Results discussion**

*Examinations*

Unilateral SNHL associated with tinnitus and/or vertigo can be a sign of a retrocochlear lesion; therefore, these patients should be examined using retrocochlear examinations (Turner et al., 1984). Of the 159 patients with asymmetric SNHL and tinnitus, 61% were investigated using retrocochlear examinations. Of the 357 patients with unilateral tinnitus, 64% underwent retrocochlear examinations. Ideally, the percentage of patients receiving these examinations should be close to 100%, as this exam is highly recommended to identify patients with a vestibular schwannoma (VS). The global incidence of VS is approximately 7.8 to 9.5 patients per million per year (Tos et al., 1992; Tos et al., 1998). Earlier retrospective studies have raised concern about the validity of ABR as a screening tool for asymmetric SNHL (Wilson et al., 1992). In several recent reports, researchers have more clearly stated their reluctance to use ABR and have called for an end to ABR testing (Cueva, 2004; Fortnum et al., 2009; SBU, 2010).

*Treatments*

The Stepped Care model is thought to be an effective treatment model that provides better access to optimal tinnitus-focused treatment and can make more resources available to patients with severe problems. An estimation based on our data is that 61% of patients went from step 1 to step 2, whereas 71% continued from step 2 to step 3, with 43% of the patients in step 1 requiring the most resource-consuming treatments (Table 5, study I). With this method, patients could reach their optimal level of care with the appropriate caregiver more quickly. To meet with the wrong caregiver could waste the patients’ time and could create a resistance in the patient to seek further treatment. Findings from a recent randomized controlled trial showed that a multidisciplinary approach could be an effective treatment method for patients with tinnitus, irrespective of the initial tinnitus severity; in addition, there were no adverse events in that trial (Cima et al., 2012).

A disadvantage in our study was that the number of patients who were included in the Stepped Care model was low, and the patient reduction effect was only 57% after two steps. The Stepped Care model applied in our ENT clinics should probably have been introduced in a better way. The fact that some ENT doctors lacked knowledge about the Stepped Care model could have affected the number of patients included in this treatment model. A more desirable model is for an audiologist who has tinnitus training and is a member of a multidisciplinary team to be the main caregiver for patients with both tinnitus and hearing loss.

A majority of our patients (56%) did not have hearing aids, even though it is likely that every patient with hearing loss was offered a hearing aid. In Östergötland, patients are always offered a hearing aid if hearing loss is detected. A similar phenomenon has been reported in other studies (Aazh et al., 2009). There are many possible explanations for why the number of
patients with hearing aids was so low, such as the stigma associated with hearing aid use, the limitations of amplification to remedy the fundamental difficulty of understanding speech in the presence of background noise, and economic issues (Kochkin, 2007). Furthermore, most of the patients had high-frequency hearing loss and could, in quiet environments, handle a conversation despite their hearing impairment. Additionally, many patients, especially men, may have difficulty accepting the fact that they need a hearing aid. In our study, the number of male patients was higher than the number of female patients. Jerram and Purdy (2001) reported a greater use of hearing aids in patients with impaired hearing who accepted their hearing loss to a greater extent than in patients who denied their condition (Jerram & Purdy, 2001). This interesting fact suggests the need to study patient motivation before, during and after a hearing aid fitting; this research currently is underway at our institution.

We found that 47% of the patients in our cohort were dissatisfied with the treatment they obtained at our ENT clinics. These patients had lower PTA and higher THI scores than those who were satisfied, and 61% of them had no hearing aids. This finding could indicate a need for further individually focused treatment/therapy/analyses in these patients. For instance, hearing aids could have an effect on the tinnitus annoyance in some patients. Hearing aids improve not only communication but also the tinnitus annoyance (Searchfield et al., 2010). We believe that all patients with tinnitus and hearing loss should be offered hearing aids, as these aids can contribute to a better hearing ability and resistance to the tinnitus annoyance.

Measurement outcomes

The results from study II showed that the female patients had a higher mean THI score compared with the male patients. However, we do not know whether this effect was related to the extent of the hearing impairment or whether the resulting reduction in sensory input led to impaired cognition as a result. This finding contradicts what was reported in a large study by Gopinath et al. (Gopinath et al., 2010). Other studies on cognition in patients with tinnitus have shown poorer results for patients with tinnitus than the control group (e.g., Rossiter et al., 2006). However, these studies concluded that future research was needed to investigate the possible effects of hearing loss on cognition and working memory in patients with tinnitus and hearing loss.

A recently published study showed a correlation between the severity of tinnitus and psychological and general health factors (Crogetti et al., 2009). However, the results of the EQ-5D questionnaire in the present study showed that the number of patients who perceived limitations/problems in their daily lives was low. This results is similar to the results from a report involving patients with hearing impairment from Östergötland, Jönköping, and Kalmar counties in Sweden (Persson et al., 2008). Moreover, depression could have an impact on the progression of tinnitus and could cause it to go from a relatively tolerable sensation to a severely annoying or even disabling sensation.

Hallam (1996) reported a higher level of tinnitus annoyance in patients who had a severe sleep disturbance (Hallam, 1996). In our cohort of patients, the middle age group had lower scores for sleep, while the other groups had relatively high scores; however, the findings show that our cohort of patients estimated their current general health to be quite good.
CONCLUSIONS

The present studies revealed a poor quality of patient information in the medical records, where information on vertigo, tinnitus, heredity, and information about patients’ other diseases and general health was often lacking.

The Stepped Care Model, despite being used only in a minority of our patients, could be an effective treatment model for patients with tinnitus that could provide better access to tinnitus-focused treatment. However, to prevent patients from dropping out of the Stepped Care model, a more desirable model is to have an audiologist with tinnitus training who is a member of a multidisciplinary team as the primary caregiver for patients with tinnitus and hearing loss.

Retrocochlear examinations in patients with unilateral SNHL associated with tinnitus were probably underperformed. This type of exam was performed in only 61% of patients with unilateral hearing loss. We believe that this exam should be performed in close to 100% of patients to identify all patients with a vestibular schwannoma.

Despite the obvious benefits of using hearing aids together with counselling, there are many patients (56%) who did not have an aid. This finding could be due to patients’ belief that nothing can be done about their situation. We believe that all patients with tinnitus and hearing loss should consider a hearing aid for any degree of hearing loss.

In our investigation, the majority of patients who were dissatisfied with their care did not have a hearing aid. It remains unclear whether this dissatisfaction was caused by their need for hearing aids or their need for other treatment options. Based on the results presented here, we recommend a more individually focused rehabilitation program.
ACKNOWLEDGEMENTS

There are a large number of individuals that have contributed, helped, inspired and pushed me during the last three years, which I want to express my gratitude to:

To my supervisor Professor Torbjörn Ledin, for accepting me as a research-student and guiding me through it. You always have been generous with your encouragement and support and have shared your enormous knowledge in audiology with me. Thank you for your great patience and to always making time for me and all my questions, guiding me in the scientific world, providing ideas and for excellent way of teaching.

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Ramesh, thank you for all your love, support and tolerance. You have not only offered me your love and passion and but also comfort me with your compassion.

Alma and Arvid, thank you for being such angels and always can make me laugh, no matter what catastrophe day I had. I am grateful for having you in my life.

Financial support for this study has been received from the County Council of Östergötland. We thank all ENT-doctors, audiologists and administrative personnel who helped us gather our data.
APPENDIX

Appendix I. EQ5D
Appendix II. THI
Appendix III. Questionnaire about patients general health

Reprint permission was provided by registration the study II at EuroQols website.
APPENDIX I

Hälsoenkät

Svensk version

(Swedish version)
Markera, genom att kryssa i en ruta i varje nedanstående grupp (så här ☐), vilket påstående som bäst beskriver Ditt hälsotillstånd i dag.

**Rörlighet**
- Jag går utan svårighet ☐
- Jag kan gå men med viss svårighet ☐
- Jag är sängriggande ☐

**Hygien**
- Jag behöver ingen hjälp med min dagliga hygien, mat eller påklädning ☐
- Jag har vissa problem att tvätta eller klä mig själv ☐
- Jag kan inte tvätta eller klä mig själv ☐

**Huvudsakliga aktiviteter (t ex arbete, studier, hushållssysslor, famojie- och friidsaktiviteter)**
- Jag klarar av mina huvudsakliga aktiviteter ☐
- Jag har vissa problem med att klara av mina huvudsakliga aktiviteter ☐
- Jag klarar inte av mina huvudsakliga aktiviteter ☐

**Smärtor/besvär**
- Jag har varken smärtor eller besvär ☐
- Jag har möjliga smärtor eller besvär ☐
- Jag har svåra smärtor eller besvär ☐

**Oro/nedstämdhet**
- Jag är inte orolig eller nedstämd ☐
- Jag är orolig eller nedstämd i viss utsträckning ☐
- Jag är i högsta grad orolig eller nedstämd ☐
Till hjälp för att avgöra hur bra eller dåligt ett hälsotillstånd är, finns den termometer-liknande skalan till höger. På denna har Ditt bästa tänkbare hälsotillstånd markerats med 100 och Ditt sämsta tänkbare hälsotillstånd med 0.

Vi vill att Du på denna skala markerar hur bra eller dåligt Ditt hälsotillstånd är, som Du själv bedömer det. Gör detta genom att dra en linje från nedanstående ruta till den punkt på skalan som markerar hur bra eller dåligt Ditt nuvarande hälsotillstånd är.
APPENDIX II

Syftet med de här frågorna är att få en bild av de problem som tinnitus orsakar just dig. Bevara var och en av frågorna genom att ringa in 'Ja', 'Ibland' eller 'Nej'. Hoppa inte över någon fråga.

Datum: 
Personnummer: 
Namn: 
Tel.-nr.: 

<table>
<thead>
<tr>
<th>Nummer</th>
<th>Fråga</th>
<th>Ja</th>
<th>Ibland</th>
<th>Nej</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Har du övats att koncentrera dig på grund av tinnitus?</td>
<td>Ja</td>
<td>Ibland</td>
<td>Nej</td>
</tr>
<tr>
<td>2</td>
<td>Har du övats att höra folk på grund av tinnitus?</td>
<td>Ja</td>
<td>Ibland</td>
<td>Nej</td>
</tr>
<tr>
<td>3</td>
<td>Gött tinnitus nog?</td>
<td>Ja</td>
<td>Ibland</td>
<td>Nej</td>
</tr>
<tr>
<td>4</td>
<td>Ört tinnitus att du kämper din förvirrad?</td>
<td>Ja</td>
<td>Ibland</td>
<td>Nej</td>
</tr>
<tr>
<td>5</td>
<td>Känner du dig desperat på grund av tinnitus?</td>
<td>Ja</td>
<td>Ibland</td>
<td>Nej</td>
</tr>
<tr>
<td>6</td>
<td>Klager du mycket över tinnitus?</td>
<td>Ja</td>
<td>Ibland</td>
<td>Nej</td>
</tr>
<tr>
<td>7</td>
<td>Hur ofta är du i en mycket stresad på grund av tinnitus?</td>
<td>Ja</td>
<td>Ibland</td>
<td>Nej</td>
</tr>
<tr>
<td>8</td>
<td>Känns det som du inte kan fly undan tinnitus?</td>
<td>Ja</td>
<td>Ibland</td>
<td>Nej</td>
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<tr>
<td>9</td>
<td>Känner du att det är svårt att uppskatta sociala aktiviteter?</td>
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<td>Känner du att det är svårt att uppskatta livet?</td>
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<td>Nej</td>
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<td>11</td>
<td>Känner du inte att det är svårt att uppskatta livet?</td>
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<td>12</td>
<td>Känner du inte att det är svårt att uppskatta livet?</td>
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<td>Nej</td>
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<tr>
<td>13</td>
<td>Försöker du med mycket betalt på grund av tinnitus?</td>
<td>Ja</td>
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<td>Nej</td>
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<tr>
<td>14</td>
<td>Möter du ofta att det är stresad på grund av tinnitus?</td>
<td>Ja</td>
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<td>Nej</td>
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<tr>
<td>15</td>
<td>Hur ofta är du i en mycket stresad på grund av tinnitus?</td>
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<tr>
<td>16</td>
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<td>17</td>
<td>Känner du inte att det är svårt att uppskatta livet?</td>
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<td>Känner du inte att det är svårt att uppskatta livet?</td>
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<td>Känner du inte att det är svårt att uppskatta livet?</td>
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<td>23</td>
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<td>Ja</td>
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<td>Nej</td>
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<td>24</td>
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<td>25</td>
<td>Känner du inte att det är svårt att uppskatta livet?</td>
<td>Ja</td>
<td>Ibland</td>
<td>Nej</td>
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(Crane et al. (1996). Övernamn: Viktor Gold & Gerhard Andersson (2002))
APPENDIX III

Hälsofrågor – självskattningsformulär

Värdera en fråga i taget, försök att värdera snabbt och instinktivt. Analysera inte och om Du har svårt att värdera... fråga Dig själv;

"Hur känner jag just nu?"

1. Vad innebär hälsa för Dig?

2. När det gäller helheten mellan hälsa och balans i livet, var befinner Du Dig på en skala 1-10?

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Din kropps fysiska hälsa

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Fysiska aktiviteter och motion

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Livsstil/Kost

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Arbetsliv/syskelsättning

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### Appendix III

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<th>Alkohol och tobak</th>
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<tr>
<td>Dålig</td>
<td>2 2 3 4 5 6 7 8 9 10</td>
</tr>
</tbody>
</table>
4. Räkna ihop Dina poling, lägsta möjliga resultat är 13 och högsta är 130, skriv ned siffran i hjärtat.

5. Om Du upplever att siffran känns låg, vad tror Du att Du skulle kunna göra för att komma ett steg vidare, på var och ett av dessa områden? Ta Dig en ordentlig tankenare... har Du förut förökat förändra Din livsstil? Tänker Du någon gång på hur Din kroppshälsa kommer att vara om 10-15 år?

6. Hur Du fått någon annan behandling utöver den Du fått på Örnsköldskiken? Om svaret är ja, Vilken vilka?

7. Vad tycker Du om behandlingen Du fått på Örnsköldskiken? Hur effektivt tycker Du att den varit?
REFERENCES


References


