A Dissertation on

LONG TERM USE OF CELL PHONE IN BUSINESS COMMUNITY CAUSING HEARING LOSS

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CERTIFICATE

This is to certify that the dissertation presented **"LONG TERM USE OF CELL PHONE IN BUSINESS COMMUNITY CAUSING HEARING LOSS"** herein by **DR.M.R.K RAJASELVAM,** is an original work done in the Department of Otorhinolaryngology, Government Stanley Medical College and Hospital, Chennai in partial fulfillment of regulations of the Tamilnadu Dr. M.G.R. Medical University for the award of degree of M.S. (Otorhinolaryngology) Branch IV, under my supervision during the academic period 2010-2013.

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DECLARATION

I, **Dr.M.R.K RAJA SELVAM**, Solemnly declare that the dissertation, titled **"LONG TERM USE OF CELL PHONE IN BUSINESS COMMUNITY CAUSING HEARING LOSS"** is a bonafide work done by me during the period of FEB 2011 to SEP 2012 at Government Stanley Medical College and Hospital, Chennai under the expert supervision of **PROF.DR.M.RAMANIRAJ, M.S., D.L.O.,** Professor, chief unit II Department Of Otorhinolaryngology, Government Stanley Medical College and Hospital, Chennai.

This dissertation is submitted to The Tamil Nadu Dr. M.G.R. Medical University in partial fulfilment of the rules and regulations for the M.S. degree examinations in Otorhinolaryngology to be held in April 2013.

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CONTENTS

INTRODUCTION

INTRODUCTION

As civilization has progressed, the noise in man's environment has increased. The adverse effect of noise is widespread with respect to human physiology and produce changes in many bio systems other than ear. It is however the ear which concerns us here.

Noise has been shown to have many effects on people such as, decrease in working efficiency, annoyance, physiological changes in blood pressure and heart rate and psychological distress. The direct auditory effects are interference with speech communication, produced due to the masking background noise, and the primary auditory effect, the capacity of noise to produce hearing loss.

Effects of noise on hearing are divided into three types. Temporary threshold shift (TTS), permanent threshold shift (PTS) and acoustic trauma (Miller 1971, Gulgnard 1973). The term acoustic trauma is limited to the effects of single exposure or relatively few exposures to high level of sound (eg.explosion). In case of acoustic trauma, the sound level that reaches the structures of the inner ear

exceed the physiologic limits of those structures frequently causes those structures complete breakdown and damage to the organ of corti.

People who experience these very high intense noise exposures may also have ear drum rupture and damaged ossicles. The hearing loss due to acoustic trauma is to a large degree and it is permanent. The precipitating episode is usually very dramatic and pronounced, in the memory of the person experiencing the event. The person involved has no difficulty in specifying the onset of the hearing problem.

Temporary threshold shift (TTS) is a short term effect which may follow noise exposure. Temporary threshold shift refers to an elevation threshold of hearing which recover's gradually following to exposure of noise. Since the noise produces a transient shift in the threshold it has become known as temporary threshold shift or even more specifically as noise induced temporary threshold shift (NITTS)

Permanent threshold shift are those hearing changes which persists throughout the life of the affected person. When a threshold shift is permanent, there is no further possibility of further recovery with passage of time following exposure.

Permanent threshold shift which results of accumulation of noise exposure repeated on a daily basis over a period of many years. This kind of hearing loss has become known as noise induced permanent threshold shift.

The loss of hearing sensitivity from chronic exposure to noise is called as noise induced permanent threshold shift if no recovery.

Apart from noise exposure at working place the gradually developing noise induced hearing loss can be caused by repeated exposures to any source of excessive volumes such as night clubs, concerts, home and vehicle stereos, environmental noise and personal media players.

Cell phones have become indispensable as communication tools. The Hearing system is in the closest proximity to device hence hearing is the most affected target of thermal and non thermal hearing effects. Additionally, the hearing system and especially the cochlear outer hair cells are known to be highly sensitive to a vast variety of exogenous as well as endogenous agents. Externally applied electric and magnetic fields are known to affect hearing sensation.

AIM AND NEED

AIM AND NEED

Noise induced hearing loss is a preventable hearing disorder. It affects people of all ages and demographic. When increased intensity is transmitted into and through the auditory system noise induced hearing loss results.

An acoustic signal from energy source such as a radio enters into external acoustic meatus and it is transmitted to tympanic membrane, which act as an elastic diaphragm and drives the middle ear ossicle system into motion which in turn transfers the mechanical energy into cochlea through oval window of cochlea. This causes fluid within the cochlea to push against the haircells stereocilia which then transmits the signal to the central auditory system.

Swelling of the hair cells following the noise exposure can lead to some cell rupturing and leads to permanent hearing loss. Hair cells also become distorted and stereocilia become fixed (Durrant,1978), and the stereocilia does not transmit energy effectively (NIH,1990),to the hair cells. Progressive damage in turn can lead to degeneration of

auditory nerve fibres and produces changes within the central auditory pathway (NIH,1990). If the number of hair cells affected is too small there may be no significant changes in hearing following early exposures.

The effects of these very small changes appear to be cumulative and that cumulative nature that makes the problem insidious. While noise induce permanent threshold shift that remains following noise induced temporary threshold shift, recovery may not be present. As with other slowly progressive conditions people with developing noise induced permanent threshold shift may develop compensatory behaviors in the early stages and so that the hearing loss may not be acknowledged. Until there is significant impact on person's life style hearing loss usually a gradual phenomenon that the person is not aware. We have to be patient with them in making them understand the situation and advice to seek help.

Hearing is the most affected special sense in humans today. It is the second most leading cause for Years lived with disability (YLD) worldwide, only behind depression. Hearing loss is responsible for 24.9 million Years lived with disability globally and gives it more

non-fatal burden than alcohol abuse disorders, osteoarthritis and schizophrenia.

According to world health organization (WHO) estimates, 63% significant auditory impairment is seen in India. With such a huge number of hearing impaired young Indians, it accounts to a severe loss of productivity, both physical and economical.

More than 50% of the cause of hearing impairment is preventable. So it was our concern to find out the impact on hearing on using mobile phones in vegetable traders in Koyambedu market in Chennai, who use mobile phones longer than the usual mobile phone users.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

Anatomy of temporal bone

Temporal bone is situated at sides and base of skull extending from the lateral calveria at the level of the external auditory canal to almost the center of the skull as it articulates with the basisphenoid.

The each temporal bone has five parts

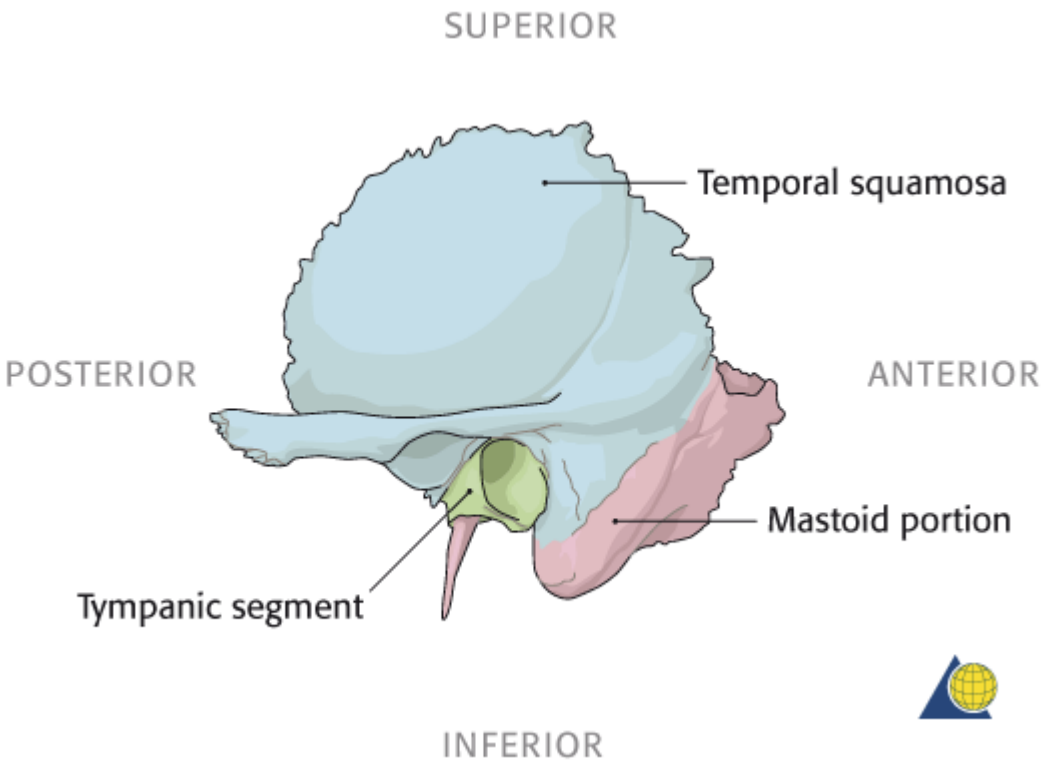
Squamous

Petrous

Mastoid

Tympanic and

Styloid process.

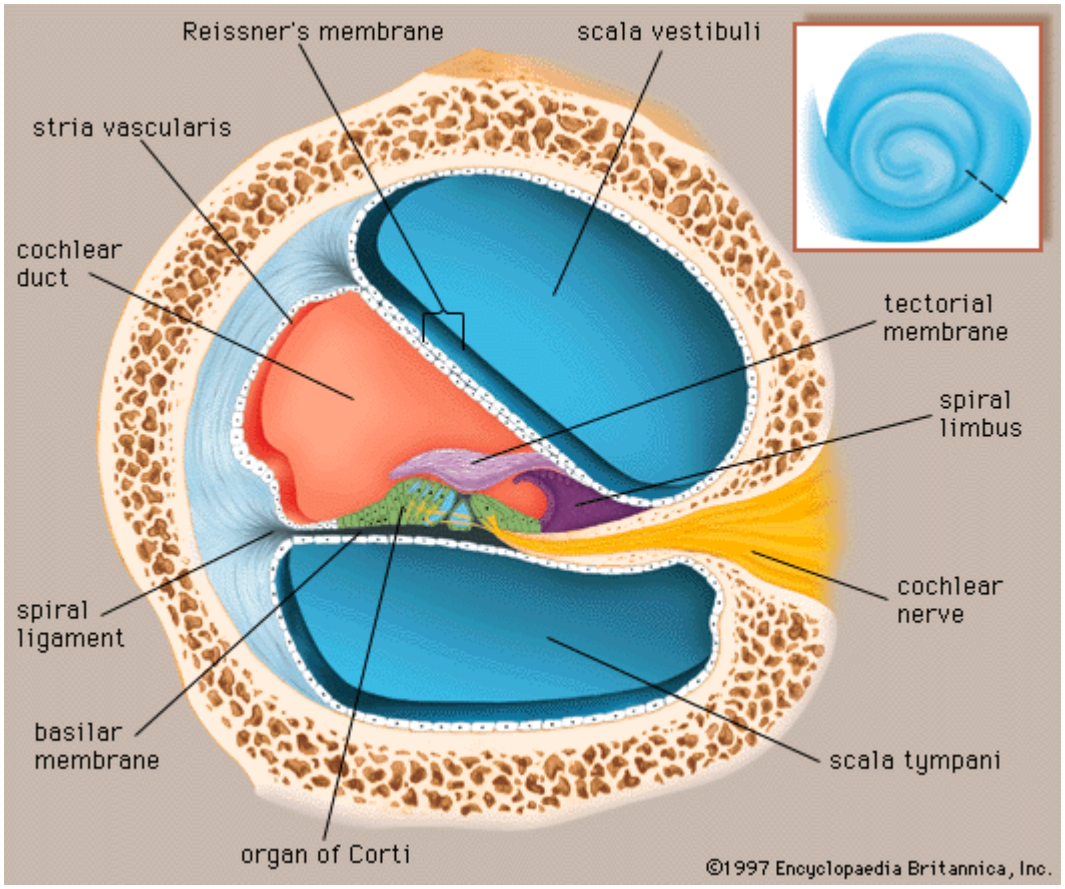


Cranial nerves V to XII course about as through the temporal bone. Middle cranial fossa lies on its superior surface and the posterior cranial fossa content lie on its posterior surface.

The internal carotid artery travels through it and internal jugular vein originates within the temporal bone in jugular foramina.

The auditory portion of the inner ear as an aggregate known as cochlea and it is encased within the petrous part of the temporal bone.

Cochlear Anatomy



Picture showing cochlear anatomy

Osteology

The inner ear is contained in the petrous apex of the temporal bone, and is encased in a bony structure called the osseous or bony labyrinth. The bone forming the cochlea and vestibular labyrinth is the hardest bone in the human body and is akin to ivory in its density. The labyrinth consists of three continuous sections: the vestibule, the

cochlea, and the semicircular canals. The initial point of communication between the middle and inner ears occurs at the oval window of the vestibule, where the stapes footplate abuts the oval window membrane. At the basal end of the cochlea is the round window membrane, which communicates with the middle ear space. The cochlea is a snail-shaped structure that has a wide diameter at the base, which narrows for 2 3/4 turns until it reaches its apex.

The core of the cochlea is the modiolus, which is highly porous bone that allows passage of auditory nerve fibers as they travel from the internal auditory meatus to the hair cell synapse. Extending from the modiolus into the osseous labyrinthine space is a bony shelf, or the osseous spiral lamina. The osseous spiral lamina coils around the center of the cochlea and provides partial division of the upper and lower cochlear chambers into the scala vestibuli and scala tympani. At the apex of the cochlea, they communicate at the helicotrema. The spiral lamina is also the point of attachment for the basilar membrane, which is the lower border of the membranous labyrinth encasing the scala media.

Along the length of the cochlea, the widths of the spiral lamina and basilar membrane are inversely related, with the spiral lamina wider at the base and narrowing toward the apex, and the basilar membrane narrower at the base and wider at the apex. This is one of several contributing factors to the frequency specificity of basilar membrane motion. At the basal turn of the cochlea is the cochlear aqueduct, a bony channel that allows communication between the perilymphatic fluid and cerebrospinal fluid of the subarachnoid space in the posterior fossa.

Vascular supply

Cochlea is mainly supplied by two main arteries that branches from the cochlear artery. These are 1) main cochlear which supplies the modiolus particularly at the upper basal, middle and the apical coils. 2) Cochlear ramus of the vestibulocochlear artery which supplies ¼ of the basal coil and modiolus. Once within the modiolus the arterial branch to from an external radiating arteriole and internal radiating arteriole. The external one travels within the interscalar septum to the lateral wall of coil and there it branches to form four capillary networks. 1) The vessels of scala vestibule with the spiral

ligament 2) the capillary network of scala vestibule 3) the vessels of scala tympani within the spiral ligament. The internal radiating arteriole supplies the medial wall of the coil and the organ of corti.

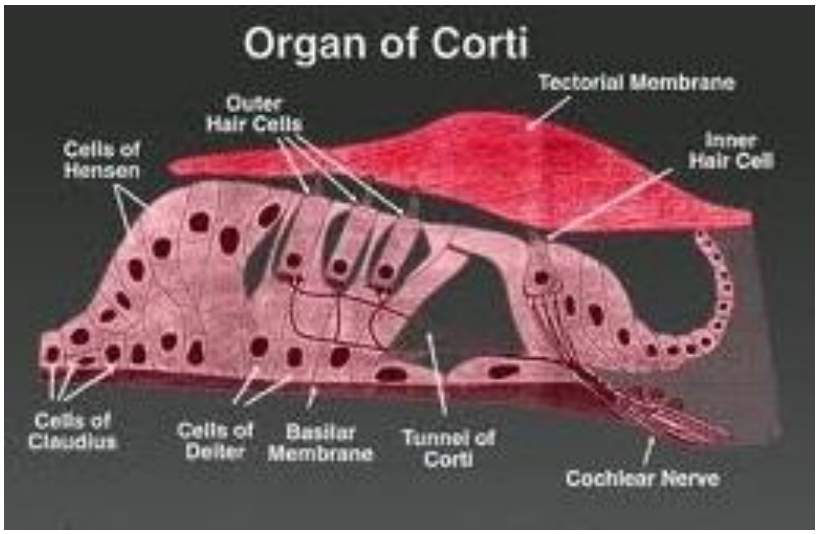
The venous drainage of inner ear is through the vein of cochlea and vestibular aqueducts. The primary drainage of cochlea is by anterior and posterior spiral veins. The posterior spiral veins drain the inferior aspect of cochlea such as spiral ganglion, scala media and scala tympani. The anterior spiral veins drain the most superolateral or more anterior cochlea such as scala vestibule and osseus spiral lamina. The veins enter as a common modiolar vein which enters the cochlear aqueduct, tributary to inferior petrosal sinus.

Membranous Labyrinth and Inner Ear Fluids:

The membranous labyrinth of the cochlea follows the shape of the osseous cochlea and forms a third cochlear chamber—the scala media. The sensory organ of hearing resides within the membranous labyrinth. The membranous labyrinth is bordered superiorly by Reissner's membrane, inferiorly by the basilar membrane, and laterally by a portion of the outer cochlear wall to which it is anchored by the spiral ligament. Within the membranous labyrinth, along the lateral wall, is the stria vascularis, highly vascular tissue that is responsible for the metabolic environment of the scala media. The intricate structures that comprise the organ of Corti are situated on the basilar membrane.

The organ of Corti runs longitudinally along the length of the basilar membrane and consists of many types of epithelial cells and structures. Medially, seated atop the osseous spiral lamina is the spiral limbus, a thickened band of periosteum that serves as the point of medial attachment for Reissner's membrane and gives rise to the tectorial membrane. The tectorial membrane lies over the inner and outer hair cells. It is a compliant gelatinous structure composed

primarily of collagen II fibers, and serves as a mass load that moves similar to a rubber band. Lateral to the spiral limbus is



the inner spiral sulcus, which is lined with the border cells of Held. One row of inner hair cells is present, and the cell bodies are surrounded by supporting cells called phalangeal cells.

Between the inner and outer hair cells lie the pillars of Corti, which originate on the spiral lamina and basilar membrane and converge at the top to form the tunnel of Corti. Lateral to this are three rows of outer hair cells, which are securely cupped inferiorly by the supporting Deiters' cells. Each Deiters' cell has a phalangeal process that projects apically, and the space between the outer hair cell and phalangeal process is referred to as Nuel's space. The phalangeal cells,

phalangeal processes of the Deiters' cells, and the superior surfaces of the hair cells form the reticular lamina, a tightly interwoven matrix that supports the apices of the hair cells. The reticular lamina forms a barrier from endolymph, the fluid in the scala media, which owing to its ionic composition is toxic to hair cells. Lateral to the outer hair cells are Hensen's cells and Claudius' cells.

The two fluid systems within the cochlea create an environment crucial to the mechanical displacement of the basilar membrane traveling wave and to the cellular depolarization and subsequent synaptic activity. Between the osseous and membranous labyrinths is perilymphatic fluid, or perilymph, which has a high concentration of sodium and low concentration of potassium, similar to what is found in cerebrospinal fluid and blood serum. The presence of perilymph in the intercellular spaces within the organ of Corti has been identified in humans and guinea pigs.

Within the membranous labyrinth is endolymphatic fluid, or endolymph, with a high concentration of potassium and low concentration of sodium, such as is typically found intracellularly. The ionic concentrations of endolymph are maintained by the cells within

the stria vascularis. The endolymphatic sac communicates with the membranous labyrinth via the endolymphatic duct and vestibular aqueduct.

Hair Cells

The inner and outer hair cells function as receptor cells that transduce mechanical movement into an electrochemical signal to stimulate the auditory nerve. The apical portion of all hair cells includes a thickened region called the cuticular plate, which in conjunction with the supporting cells forms the reticular lamina. Rooted in the cuticular plate of each hair cell and projecting through the reticular lamina are bundles of actin filaments called stereocilia, stiff hair like structures that deflect with mechanical disturbances. Adjacent to this is a noncuticular region that contains a rudimentary kinocilium.

Inner hair cells are flask-shaped, receive extensive afferent innervation, and receive indirect efferent innervation. Outer hair cells are cylindrical and receive direct afferent and efferent innervation.

There are approximately 3500 inner hair cells arranged in one row on the modiolar side of the tunnel of Corti and 12,000 outer hair cells in three rows on the strial side. The stereocilia on outer hair cells form a “V” or “W” shape with the bottom facing away from the modiolus. The inner hair cell stereocilia form a shallow “U” that opens toward the modiolus. On each hair cell, there are rows of stereocilia, two or more on inner hair cells, and three or more on outer hair cells. For both types of hair cells, the stereocilia lengths are graduated from longest on the strial side to shortest on the modiolar side. The longest stereocilia on the outer hair cells contact the tectorial membrane, which results in deflection of the stereocilia with basilar membrane movement. The stereocilia are connected to each other by filamentous links laterally by cross-links and from the tips of shorter stereocilia to the sides of the taller ones by tip-links. These ensure that the connected stereocilia move as a unit when the longer stereocilia are deflected.

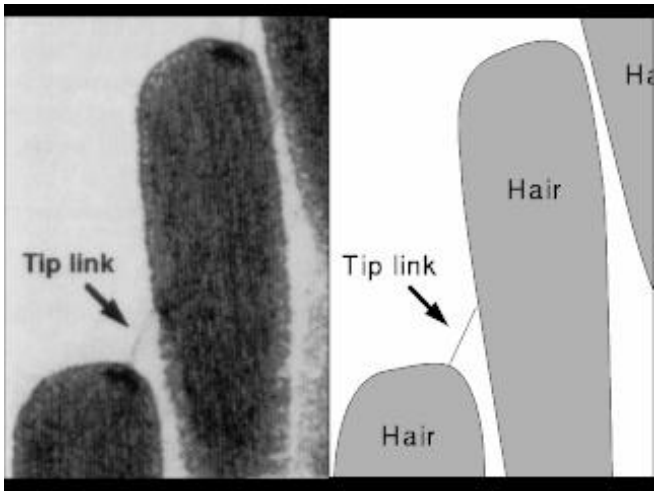
The structural aspects of the inner and outer hair cell bodies themselves differ significantly and are reflective of their functional differences. The inner hair cells are flask-shaped, wide at the bottom and narrower at the top, and contain high concentrations of organelles

that are involved in metabolic activity, particularly Golgi bodies and mitochondria. Although highly metabolic, inner hair cells are considered to be passive transducers in the auditory system.

Outer hair cells are cylindrical in shape and contain microfilaments and microtubules along the length of the cell that give rise to motile activity. The motile properties have been shown empirically to result in highly tuned, frequency-specific contractile activity even when stimulated in isolation from the basilar membrane. All hair cells have synaptic bars at afferent synapses, which serve as sites for presynaptic vesicle docking and release for subsequent stimulation of auditory nerve fibers.

Innervation

Afferent innervation of the cochlear hair cells consists of approximately 30,000 auditory nerve fibers in humans, and is responsible for providing ascending information from the cochlea to the central auditory system. The cell bodies of afferent fibers make up the spiral ganglion that resides in Rosenthal's canal within the modiolus. Nerve fibers reach the hair cells by traveling through the modiolus, and into the osseous spiral lamina, where they pass through



Stereocilia showing tip links

holes in the lamina referred to as the habenulae perforatae. The nerve fibers are classified as type I and type II.

Type I fibers are bipolar, of large diameter, and myelinated, and they constitute nearly 95% of the total number of fibers. Each type I fiber has a direct and independent synapse on the body of a single inner hair cell, and each inner hair cell is innervated by approximately 20 such fibers. Type II fibers constitute the remaining 5%, and are smaller and may be myelinated or unmyelinated. Type II fibers synapse directly on the outer hair cells, with a single fiber diverging to form branches that synapse with multiple other outer hair cells.

The efferent auditory pathway originates from the olivocochlear bundle and provides central inhibitory modulation of hair cell activity via descending information. The olivocochlear bundle has about 1600 fibers, and these constitute the uncrossed olivocochlear bundle and crossed olivocochlear 12bundle.These pathways originate from the medial superior olive (MSO) and lateral superior olive (LSO) regions on both sides. For the uncrossed olivocochlear bundle, the LSO projects many small-diameters, unmyelinated efferent fibers toward the ipsilateral inner hair cells, where they synapse with the afferent fibers. The MSO projects fewer myelinated fibers ipsilaterally that synapse directly on the outer hair cells. For the crossed olivocochlear bundle, the MSO projects large-diameter myelinated fibers to the contralateral outer hair cells, and the LSO projects a few unmyelinated fibers to the contralateral inner hair cell afferents. The fibers from the crossed olivocochlear bundle cross midline at the level of the fourth ventricle.

Physiology of hearing

Middle ear Mechanics

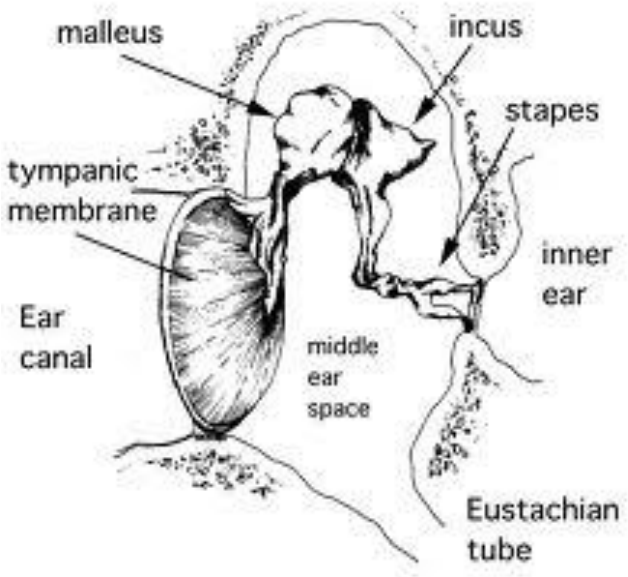
The middle ear is composed of the tympanic membrane, the ossicles (malleus, incus, and stapes), and the stapedius and tensor tympani muscles. As a sound stimulus enters the external auditory canal, it causes the tympanic membrane to vibrate. The malleus, which is coupled to the tympanic membrane, vibrates in response to the motion of the tympanic membrane. This causes the entire ossicular chain to vibrate, resulting in sound transmission to the inner ear via the stapes footplate.

This pathway of sound transmission is referred to as ossicular coupling. The ossicular chain has two synovial joints that are mobile: the incudomalleal and the incudostapedial joints. The ossicular chain vibrates along an axis that projects through the head of the malleus and the body of the incus in an anterior-to-posterior direction. The stapes, the smallest bone in the body, transmits the output of the middle ear into the inner ear through the oval window.

Acoustic mechanism in middle ear sound transfer

Because the inner ear is fluid-filled, if the sound stimulus strikes the inner ear fluid directly, most of the acoustic energy is deflected, as the impedance of fluid is much greater than the impedance of air. The pathway of sound transmission to the inner ear in the absence of the ossicular system is referred to as acoustic coupling.

Picture showing the pathway of sound transmission



It has been shown that the difference between ossicular coupling and acoustic coupling is about 60 dB, which is the maximal amount of hearing loss expected in patients with ossicular discontinuity. The middle ear plays an important role in the process of "impedance matching" between the air-filled middle ear and the fluid-

filled inner ear, allowing for efficient sound transmission. The most important factor in the middle ear's impedance matching capability comes from the “area ratio” between the tympanic membrane and the stapes footplate. The human tympanic membrane has a surface area approximately 20 times larger than the stapes footplate (69 vs. 3.4 mm^2). If all the force applied to the tympanic membrane were to be transferred to the stapes footplate, the force per unit area would be 20 times larger on the footplate than on the tympanic membrane.

A second mechanism for impedance matching is called the lever ratio, which refers to the difference in length of the manubrium of the malleus and the long process of the incus. Because the manubrium is slightly longer than the long process of the incus, a small force applied to the long arm of the lever (manubrium) results in a larger force on the short arm of the lever (incus long process). In humans, the lever ratio is about 1.31: 1. The combined effects of the area ratio and the lever ratio give the middle ear output a 28-dB gain theoretically. In reality, the middle ear sound pressure gain is only about 20 db. This is mostly due to the fact that the tympanic membrane does not move as a rigid diaphragm. At higher frequencies, it vibrates in a complex manner, with multiple areas that vibrate differently. The effective area

of the tympanic membrane involved with impedance matching is smaller than its total area.

Transmission of sound in inner ear

As sound energy travels through the external and middle ears, it causes the stapes footplate to vibrate. The vibration of the stapes footplate results in a compressional wave in the inner ear fluid, which travels across the scala vestibuli, around the helicotrema, and out across the scala tympani toward the round window. An inward motion of the stapes causes an outward motion of the round window. As this compression wave travels across the scala vestibuli, however, the pressure in the scala vestibuli is higher than the pressure in the scala tympani. This sets up a pressure gradient, which causes the cochlear partition to vibrate.

Von Bekesy first described the vibration of the cochlear partition in cadaveric human cochleas. He showed that as the cochlear partition is deflected by the compressional wave created by the stapes footplate vibration, it sets up a traveling wave on the basilar membrane, which travels from the base of the cochlea to its apex. von Bekesy also found that the basilar membrane varied in its stiffness

along its length, with higher stiffness near the base and lower stiffness near the apex. This property of the basilar membrane allows it to respond to various frequencies differently (i.e., the amplitude of the traveling wave peaks [resonates] at a specific place along the basilar membrane), with the higher frequencies at the base and the lower frequencies toward the apex. The basilar membrane is able to act as a series of filters, responding to specific sound frequencies at specific locations along its length. In other words, the basilar membrane is tonotopically tuned to different frequencies along its length. Von's seminal work on cochlear mechanics earned him the Nobel Prize in Physiology or Medicine in 1961.

Because potassium is the major cation in the endolymph, it is believed that potassium current plays an important role in triggering the signal transduction process in hair cells. When inner hair cells are depolarized, voltage-gated calcium channels open. These voltage-gated calcium channels are clustered in several "hot spots" along the basolateral surface of the inner hair cells, where synaptic contacts with primary afferent auditory nerve fibers are located. The calcium current mediated by these voltage-gated ion channels are important for triggering neurotransmitter release across the synapse, which leads to

activation of the auditory nerve fibers. The neurotransmitter involved in this process has not been definitively identified, but is believed to be a molecule closely related to glutamate.

In contrast to the inner hair cell, an outer hair cell can also change its length in response to voltage changes; it contracts with depolarization and elongates with hyperpolarization. The molecular motor that is associated with rapid changes in outer hair cell length is a voltage-dependent, integral membrane protein called prestin. The change in outer hair cell length in response to voltage changes is believed to add energy into the basilar membrane motion through a mechanical feedback scheme. In other words, the outer hair cell acts as a cochlear amplifier, augmenting the signals transmitted into the inner ear by the stapes vibration.The importance of prestin in hearing is supported further by the finding that in animal studies in which prestin has been knocked out or altered, the hearing sensitivity and frequency selectivity are impaired.

Because different regions of the basilar membrane are tonotopically tuned to specific frequencies, and because the hair cells reside on top of the basilar membrane, it is logical to assume that the

hair cells from different regions are also tonotopically tuned to specific frequencies. The frequency tuning curves for outer and inner hair cells have been recorded in guinea pigs in response to various frequencies, and the hair cells in different regions along the basilar membrane are tonotopically tuned to specific frequencies that correspond to the tonotopic arrangement of the basilar membrane .The frequency to which a hair cell is most sensitive is called the characteristic frequency. As discussed subsequently, this tonotopic arrangement is essential for the processing of auditory information, and is preserved throughout the entire auditory pathway.

Theories of hearing

1. Von Bekesy ‘s travelling wave theory (1960)

This states that in response to a sound stimulus at the oval window the wave begins from the base and moves towards the apex. Travelling wave is independent of frequency. High pitched sounds cause a short travelling wave not beyond the basal turn, while low pitched sounds cause maximum displacement near the apex. Middle frequency changes occur in between these two

1. Helmholtz ‘s place theory (1883)

States that basilar membrane acts as a series of tuned resonators similar to a piano string. Each pitch would cause resonant vibration of basilar membrane which is particular to its own place and not on the entire basilar membrane.

2. Rutherford’s frequency/telephone theory (1886)

It states that all frequencies activate the entire length of the basilar membrane along with the hair cells .Also, the rate of firing of the auditory nerve fibres determine the frequencies.

3. Wever’s volley resonance theory (1949)

Combines both the place and telephone theories postulating that

High frequencies (5000 Hz)are perceived in basal turns

Low frequencies (1000 Hz) stimulate nerve action potential equal to frequency stimulation.

Intermediate frequencies (1000 – 5000 Hz) are represented in the nerve by asynchronous discharges which then combine actively to represent the frequency of stimulus.

Theories of bone conduction

1. Inertial theory

The skull is set into vibration by the sound stimulus but the ossicles lag behind due to inertia. The out of phase movements of the skull and ossicles leads to a piston movement of the stapes footplate at the oval window

2. Compressional theory

The skull bones including the bony labyrinth in response to the sound stimulus sets the fluid of inner ear into vibration

3. Osseo tympanic theory

When the skull vibrates due to sound stimulus the mandible also sets into vibration which lags behind due to inertia. The out of phase movements of the skull and mandible leads to vibration of the air in the external auditory canal which in turn vibrates the tympanic membrane.

Auditory pathway

Auditory nerve

↓

Cochlear nucleus

↓

Superior olivary nucleus

↓

Lateral lemniscus

↓

Inferior Colliculus

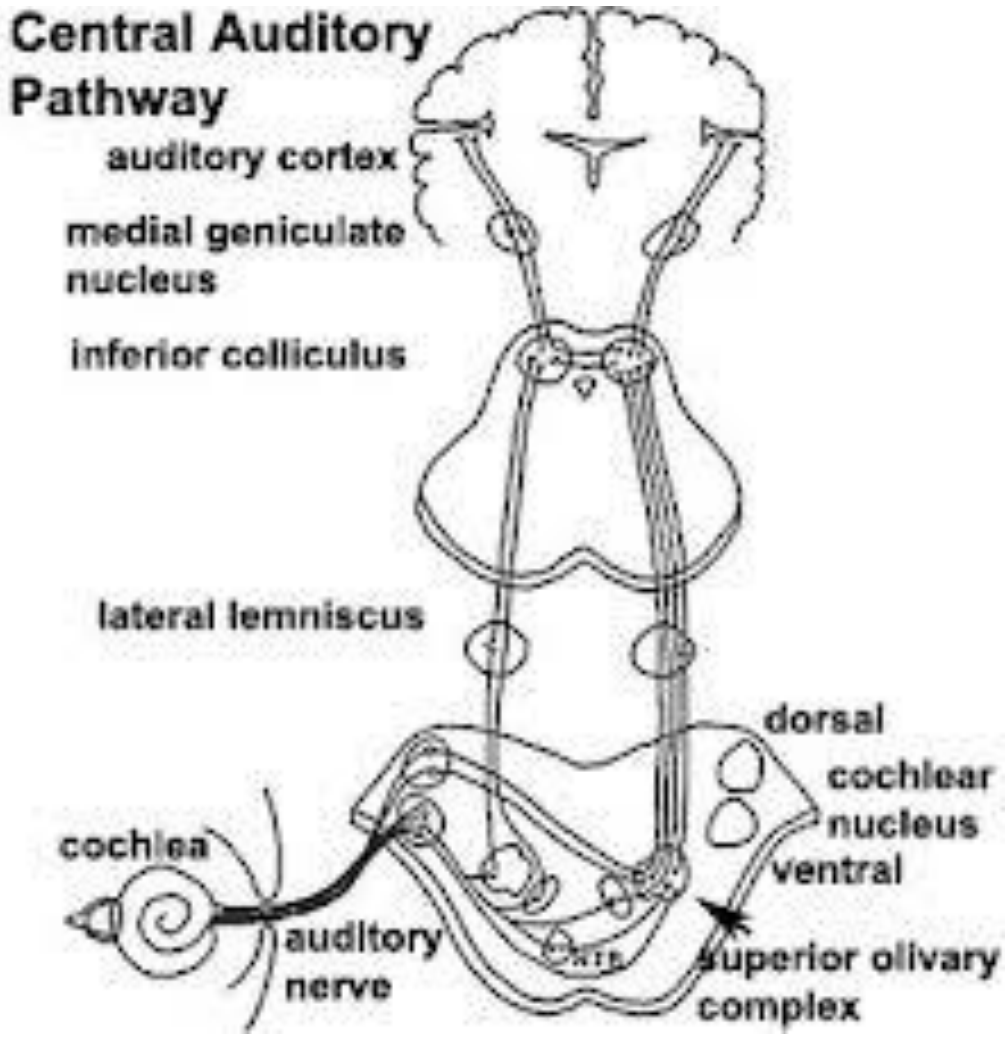
↓

Medial Geniculate Body

↓

Auditory Cortex

Auditory pathway



Cell phones systems and standards

Cell phones operate in radiofrequencies that ranges from 450,800/900 and 1800/1900 MHz .The first cellular systems were the total access communication systems (TACs) in which the phones had a nominal output of 0.63Watts, with frequency channels of about900MHz, systems that uses the total access communication systems (TACs), have been replaced by the global system for mobile communications (GSM).

European digital phone standard that functions around 900 or 1800MHz band.

In order to raise the number of consumers who can communicate with base station simultaneously, a technology called Time division multiple access (TDMA) is employed. It allows each channel to be used by eight phones .The maximum global system for mobile communication phones allowed to transmit by the present standards is 2 Watts (900Hz) and 1Watt (1800 Hz) .

The third generation of Mobile telecommunication technology is called Universal Mobile Telecommunication Systems (UMTS) and worldwide it is known as International Mobile Telecommunications - 2000 (IMTS – 2000).

The frequency band used for this system are 1885 – 2010 and 2110- 2200 MHz

The code division multiple Access (CDMA) can be used by many users simultaneously and the frequency channel have 5 MHz bandwidth. In code division multiple Access (CDMA) a transmission is labeled by a coding scheme which is different in different users.

Two types of code division Multiple Access are likely implemented,

1. Frequency Division Duplex (FDD) were separate 5MHz are used for both the directions that is from and to mobile phones.
2. Time Division Duplex (TDD) were the same channel is used but in different time slots.

In Frequency Division Duplex (FDD) there is fast power control with the periodic update frequency of 1500Hz while the Time Division Duplex (TDD), the pulse frequency can vary from 100-800 Hz.

Cordless phones are usually used at very short ranges between a base station located at the Telephones socket outlet within the house or office and the cordless phone handset

Cordless phones used analog technology earlier and now it is replaced by a Digital System Enhanced Cordless Telecommunications (DECT), which operated in similar frequencies around 1850MHz to that of cellular phones.

The new Terrestrial Enhanced Trunk Radio system technology (TETRA) is not intended for public systems connected to telephone network. It is designed for closer groups. It is coming into use for emergency services and commercial applications. Frequency Bands that are available are 400 and 900MHz.

SPECIFIC ABSORPTION RATE

It is a measure of rate at which energy is absorbed by the body when it is exposed to Radiofrequency Electromagnetic field.

It is measured in Watts /Kg.

Specific Absorption rate is usually calculated for the whole body or over a small sample volume (1gm or 10 gm. of human tissue) .

Calculation;

It is calculated from the Electric field within the exposed part of tissue

$$SAR = \int sample \frac{\sigma(r)\,[E(r)]^2}{\dot{\rho}\,(r)}$$

σ - is sample electrical conductivity

E- is root mean square electric field

ṕ-is sample density

SAR measures exposure to field between 100 KHz – 10GHz.

The value will depend mainly on the part of the body exposed and the location of the Radiofrequency source.

The Measurement of SAR for a mobile phone, is done while the subject holding the phone in the talking position, the point at which highest Absorption rate in the entire head is used for measurement.

In United States, the Federal Communication Commission (FCC) recommends SAR value of about 1.6 Watts/kg (containing a mass of 1gm of tissue).

In European Countries, CENELEC suggest following International Electro technical Commission (IEC), which recommends SAR value

2 watts/Kg (containing 10gm of tissue).

In India, Department of Telecommunication (DoT), presently recommends SAR value of 2watts /Kg (containing 10gm of tissue).

Mobile phones and their SAR list

Brand	Model	Operating system	SAR (watts/Kg)
HTC	Nexus one	Android	0.37
Blackberry	Torch	Blackberry –os 60	0.91
Samsung	Blue earth		0.196
Nokia	E5	Symbian	0.88
Apple	iPhone 4	i-os 51	0.93
Motorola	Bravo		1.59
Sony Erricson	Xperia X10 minipro	Android 2.1	1.55

Department of Telecommunication (DoT) in India has set a deadline that after 1st September 2013 , only mobile phones with Revised SAR value of 1.6 watts/Kg (containing 1gm of tissue) ,

would be permitted to be manufactured or imported within our country ..

Cell phones transmits and receive microwave radiations mainly at frequencies between 800-2000MHz, which causes rotation of water molecules and some organic molecules causing thermal and non thermal effects on the exposed structures of humans. Thermal effects include sensation of warmth of ear, burning sensation over the facial skin, headache, and alteration in blood brain barrier. Non thermal effects include alterations in blood pressure value, sleep disturbances and effects on cognitive functions.

Some studies conducted earlier show that acute exposure to cell phone microwaves does not influence the cochlear outer hair cell functions in vitro and in vivo.

1. Another study show acute exposure to mobile phones for 30 minutes has no short term adverse effects on human auditory system. It is also observed that with an increase in duration of mobile phone use, and with age more than 30, high frequency hearing loss and absent distortion product otoacoustic emissions were noticed.

2. Oysu et al studied the short term effects of cellular phones electromagnetic exposure with the use of auditory brainstem response in 18 healthy human volunteers by placing mobile phones in contact with the right ear for 15 minutes. The volunteers underwent auditory brainstem response prior to and immediately after exposure. The results show that acute exposure to electromagnetic radiation of mobile phones does not change the absolute latencies and the interwave latencies of auditory brainstem response. Also the author insists that excessive cellular phone use should not be encouraged as minor biological and neurophysiological effects may not be detectable by current technology. In addition long term effects of mobile phones use were not investigated.

3. Ozturan et al investigated the effects of electromagnetic radiation exposure in cochlear sensitivity with the use of transient evoked otoacoustic emission .30 volunteers with having normal hearing were exposed to cellular phone electromagnetic radiation for 10 minutes . All volunteers were examined with transient evoked otoacoustic emissionprior to

and after exposure. The results showed none of the subject had worsening in hearing level and there was no measurable change in transient evoked otoacoustic emission. Since the study was designed to investigate the short term exposure of electromagnetic radiation from mobile phones it does not reveal any information regarding the potential effects of long term exposure or chronic cumulative exposure

4. Counter et al investigated the effect of long term Trans cranial electromagnetic stimulation in auditory brainstem and cortical evoked response over a period of one year in rabbits. Rabbits were exposed to electromagnetic radiation using a magnetic coil placed over the right ear while the left ear was protected. Differences were recorded after the exposure with the use of auditory brainstem response .No significant changes were noted.

5. Kellinyi et al reported that pulsed electromagnetic radiation transmitted by the mobile phone for 15 minutes causes delay in wave$V$ of auditory brainstem response. Garcia reported mild

hearing loss in cell phone users, yet the changes cannot be definitely linked with electromagnetic field.

6. Recently Davidson and Lutman reported no chronic effects of mobile phone usage in hearing, balance and tinnitus in student population. Vestibular function has also been studied with the help of electronystagmography prior to and after exposure to continuous and pulsed electromagnetic field. No abnormal nystagmus associated with electromagnetic field indicating that there are no harmful effects on semicircular canals. Also they used ultra red thermograph to measure the increase in temperature close to cell phone antenna and found it is around < 0.1 degree Celsius which is insignificant.

7. Noritoshi et al investigated in 15 healthy volunteers who have normal hearing by exposing them to cell phone radiation for half an hour and auditory brainstem response was studied. In waves I, III, V no changes were noted in auditory brainstem response indicating that short term exposure to cellular phones does not affect stimulus transmission along auditory pathway.

8. Some statisticalanalysis shows no significant differences in the mean hearing threshold levels (HTL) of pure tone audiometry and means shifts of transient evoked otoacoustic emissions which were recorded before and immediately after 10 minutes of electromagnetic fields of mobile phones.

Studies describing various problems like tinnitus, headache, ear warmth, sleep disturbances, memory changes and tremors were significantly higher among exposed inhabitants under mobile towers than control.

MOBILE PHONE USE AND CANCER

There is a significant public concern regarding a possible increase incidence of brain tumor in cell phone users, in spite of the absence of known biological mechanism by which radio frequencies from cellular phones might lead to carcinogenesis. Due to the proximity of the ear exposed to the electromagnetic radiation from mobile phones, the acoustic nerve would be of particular concern from where acoustic neuroma arises. Reports from literature are so far contradictory.

Shoemaker et al investigated case control studies in six group of population to rule out acoustic neuroma in relation with mobile phone use. Study involved 678 cases and 3553 controls in United Kingdom and 4 Nordic countries. The study show there was no risk of development of tumor with the use of mobile phone. The study suggested that there is no significant risk of acoustic neuroma in the first decade of life after start using mobile phone, but an increase in risk in using mobile phone for long time cannot be ruled out.

Lonn et al population based case control study with cases of aged 20 to 69 years diagnosed with acoustic neuroma during the

period of 1999 to 2002 in Sweden. The results indicate that there is no increased risk of acoustic neuroma in relation to short term mobile use , however suggested that increase in risk of acoustic neuroma if the mobile phone is used for at least ten years period.

Lennart et al in a study of 107 patients with acoustic neuroma suggested that the risk of acoustic neuroma with the use of cell phone is statistically insignificant when compared to whom never or rarely used the cell phone. But also noticed that the mean tumor size is larger in regular users of cell phone than whom never or rarely uses the cell phone.

A case control study series of benign brain tumors of 413 cases in which 305 –meningiomas

84-acoustic neuromas

24-other types of tumors

With 692 controls were studied to correlate between acoustic neuroma and meningioma with use of cell phones or other cordless phones.

The study show a significant risk factor for both acoustic neuroma and meningioma

Some other studies suggested that children are more sensitive to the electromagnetic radiation when compared to adult due to the smaller diameter of the head and specific absorption rate (SAR) is higher in children.

In another study correlation between glioma and cell phone use is investigated in adults.Total subjects of 966 were taken in age group between 18 to 69 years who were diagnosed with glioma and 1716 control was randomly selected. The study shows no correlation between the tumor developments with the use of cell phones.

At the same time there is an excess risk of tumor development in ipsilateral side of mobile phone use when compared to the contralateral side. Supporting to this study from Germany also show that there is an increase in risk of glioma and not for meningioma in the mobile phone users

Studies were also conducted to show the correlation between mobile phone and ocular melanomas. Studies showed that there is no consideration of exposure to ultraviolet radiation which is a known risk factor for ocular melanoma.

It has been shown that electromagnetic radiation cannot induce changes in mutation rate in fungi, and in lymph cells in mice.

Many studies regarding the genotoxicity of the radiofrequency radiation is carried out in which the radio frequency used is in and around frequency bands of mobile phone telecommunications. In particular the heating effect of higher intensities complicate the interpretation since the thermal effects alone can be genotoxic or it can enhance the action of the genotoxic agents.

Some reports shows that electromagnetic radiation directly affects the DNA, which causes various errors like

Unusual multiple DNA breakages,

Abnormal apoptosis.

Increased number of single stranded and double stranded DNA breaks was reported in brain cells of rats which were exposed to 2 hours to continuous or pulsed wave of 2.45 GHz. Moreover this effect was blocked by treating the rats with melatonin on free radical scavengers before or exposure to electromagnetic radiation.

Electromagnetic radiation has been associated with increase in carcinogenic rates when they are combined with known carcinogenic agents.

Szmigielzki et al showed that increase in risk of mammary tumors and skin tumors in mice when the mice are exposed to benzopyrene repeatedly along with chronic exposure to electromagnetic radiation.

Another study by Maes et al showed the enhancement effects of mitomycin C on human lymphocytes following exposure to electromagnetic radiation of intensity 935MHz for two hours which is statiscally significant but very small.

On the other hand, several studies show that the tumor incidence is unaffected by electromagnetic radiation.

Wu et al showed that chronic exposure to electromagnetic radiation had no incidence in the size of the colon cancers induced in mice by dimethyl hydrazine.

Imanda et al found no effect of exposure at frequency of 14399Hzfor weeks using standard medium promotion time rate tumor promotion model in which the neoplastic changes are induced in liver by diethyl nitrosamine.

The international agency for research into cancer (IARC), a part of the world health organization (WHO) had classified the mobile phones to “group 2B” category.

The international agency for research into cancer says that the mobile phones pose a health risk was limited for two types of brain tumors.

i. Glioma and

ii. Acoustic neuroma.

and inadequate when it comes to other kinds of tumor.

The carcinogenic effects of electromagnetic fields emitted from mobile phones remains controversial.

According to The international agency for research into cancer there are five possible categories of risk.

Group 1:

Strong evidence for cancer- e.g.; smoking, alcohol,asbestos and so on.

Group 2A:

Things those are “Probably carcinogenic to humans”. Here the evidences are “limited” in humans but “sufficient” studies from animal.

Group 2B:

Things those are “possibly carcinogenic to humans”. Mobile phones fall under this category. It means there is “limited evidence” that something causes cancer in humans. Even the evidence from animal studies is “less than sufficient”

Group 3:

The evidence of causing cancer is inadequate in humans and inadequate or limited in animals.

Group 4:

Something that does not cause cancer in humans.

In summary, it is concluded that electromagnetic radiation may cause carcinogenesis, amplify the effect of carcinogenic agents and accentuate the development of tumors.

Neither short term nor long term exposure to electromagnetic radiation can affect the mutation rate of chromosome, when the ambient temperature is within normal limit.

Therefore even though it has been suggested that electromagnetic radiation is related with increase in incidence of

specific tumor and may interact with known carcinogenic agents, there is no conclusive evidence that exist to support its role in tumor development.

MATERIALS AND METHODOLOGY

MATERIALS AND METHODOLOGY

Cross sectional study

N=90

Age group: 18-50 years

Year of study: 2010 -2012

Inclusion criteria

- 18 – 50 years of age
- Healthy male vegetable traders
- Any type of mobile phones
- Normal intact tympanic membrane

Exclusion criteria

- Any history of any other co morbid illness like hypertension, diabetes mellitus, cardiac illness.
- Any ear disease which have hearing loss
- Any surgery to the ear with no improvement of hearing after surgery.
- Any intake of ototoxic medications.

METHODOLOGY

- Questionnaire
- Otoscopic examination
- Pure tone audiometry
- Master chart made

The procedure recommended by Roystus (1999) to do an analysis of year to year audiometric variability as described in American national standard institute (ANSI) S12-13-1991 had been followed. Using this procedure each set of annual audiogram is compared with previous year data. The data are evaluated to determine the percentage of population whose hearing got worse if any.

90 healthy male vegetable traders in the age group of 18 to 50 in Koyambedu market in Chennai had been selected for the study. The participants were enquired about the literacy levels, awareness of their health, and were habits free (pawn chewing, Hans, alcohol free and non-smokers). We got the prior consent from them and enlightened them about noise induced hearing loss.

We made sure that the person tested is given ample opportunity for any temporary threshold shift resulting from recent loud noise

exposure to recover or excluded from the study thus preceding hearing test be “noise free”. Noisy vocational activities are cautioned (loudmusic, power tool use,) during that period

Procedure

Pure tone audiometry including the following frequencies 500 Hz, 1000 Hz, 2000 Hz, 3000 Hz, 4000 Hz, and 6000 Hz for each ear was taken separately.

First a baseline pure tone audiometry was done just after the noise free period, and the second audiometry was repeated on the first day of the continuous use of mobile phone after the busy hours which were in between 2 AM to 5 AM.

Then the third audiometry and fourth audiometry were performed just after one and two years after the first audiometry around the same period of baseline audiometry.

Routine health checkups were conducted periodically to ensure that candidates will not go in for hearing loss during the survey period.

QUESTIONNAIRE

NAME

AGE

SEX

OCCUPATION

ADDRESS

ANY OTHER NOISE EXPOSURE

YES / NO

PAST HISTORY

- H/O DIABETES MELLITUS,HYPERTENSION,CARDIAC ILLNESS
- H/O EAR DISEASE WHICH HAVE SENSORINEURAL HEARING LOSS
- H/O ANY EAR SURGERY WITH NO IMPROVEMENT OF HEARING
- H/O OTOTOXIC DRUGS

FAMILY HISTORY

YES / NO

EAR SYMPTOMS

- EAR WARMTH

  YES / NO

- TINNITUS

  YES / NO

- EAR FULLNESS

  YES / NO

- EAR DISCHARGE

  YES / NO

EXAMINATION OF EAR

EXTERNAL AUDITORY CANAL

RIGHT

LEFT

TYMPANIC MEMBRANE

RIGHT

LEFT

PURE TONE AUDIOMETRY

RIGHT

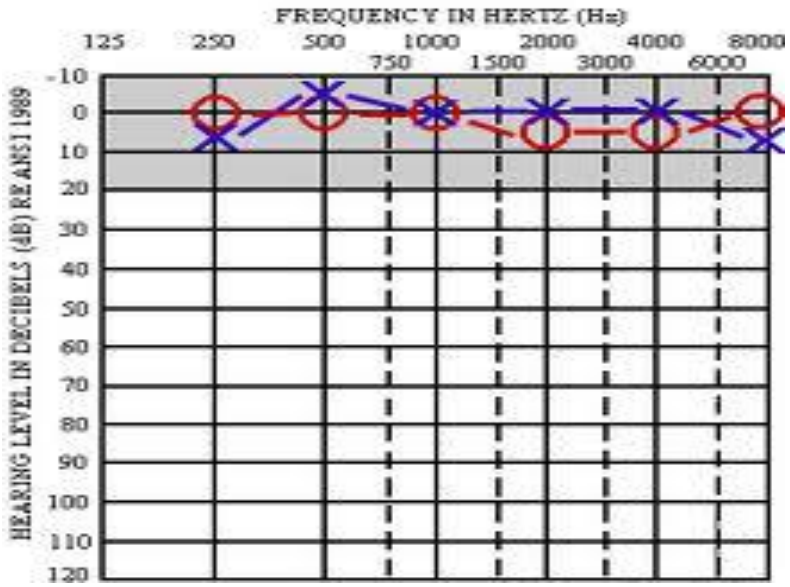
LEFT

IMPRESSION

Pure tone audiogram

Pure tone audiometry is the most commonly used test for evaluating auditory sensitivity. Auditory pure-tone signals are delivered primarily through air conduction and bone conduction. The American National Standards Institute (ANSI) defines the threshold of audibility as "the minimum effective sound pressure level of an acoustic signal producing an auditory sensation 'in a specified fraction of the trials.' " Most often, threshold is defined as the lowest signal intensity at which multiple presentations are detected 50% of the time.

Pure tone audiogram showing normal hearing



When used clinically, audiometric threshold data are most often displayed on a graphic plot called an audiogram. Various symbols are used to represent data obtained for the right and left ears by use of air-conducted and bone-conducted signals. The current audiogram representation was recommended by the American Speech, Language, and Hearing Association in 1974, and was adopted by ANSI S3.21-1978. Data are presented in hearing level (HL), which is calibrated to referent sound pressures (ANSI S3.6-1969, 1970) that represent the hearing sensitivity of normal young adults when tested under reasonably quiet test conditions. An audiogram represents a patient's ability to hear sounds compared with the hearing sensitivity of a group of normal young adults

Background noise in audiometric testing as per American national standard institute (ANSI) standard (S3.1-1999) that clearly defines acceptable ambient sound pressure levels and the associated errors in threshold measurement were considered.

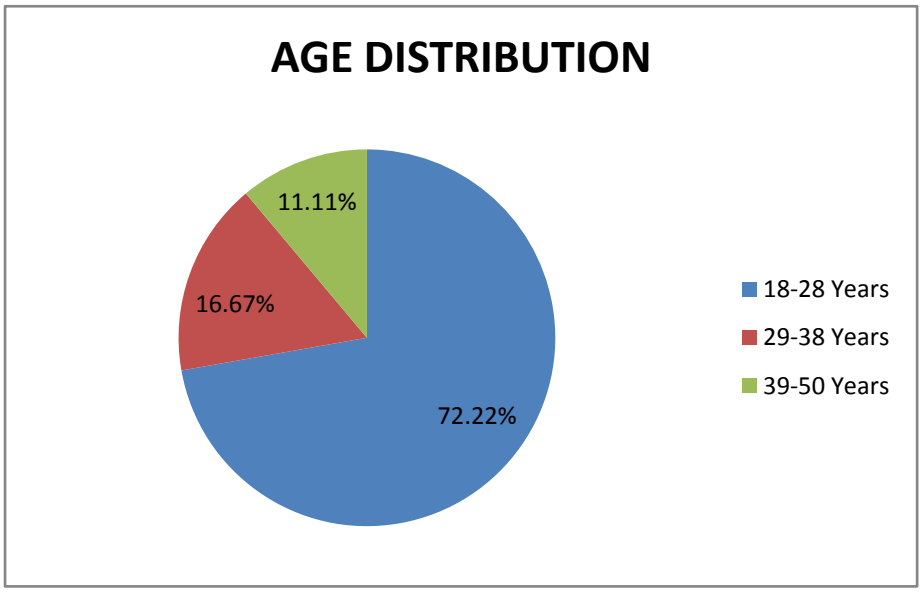
As per American national standard institute (ANSI) and Occupational safety and health administration (OSHA), we have kept 10dB HL as minimum hearing level as standard instead of 0dB HL.

OBSERVATION AND RESULTS

OBSERVATION AND RESULTS

AGE INCIDENCE

Age (in	Total
18-28	65(72.22%)
29-38	15(16.67%)
39-50	10(11.11%)
Total	90(100%)



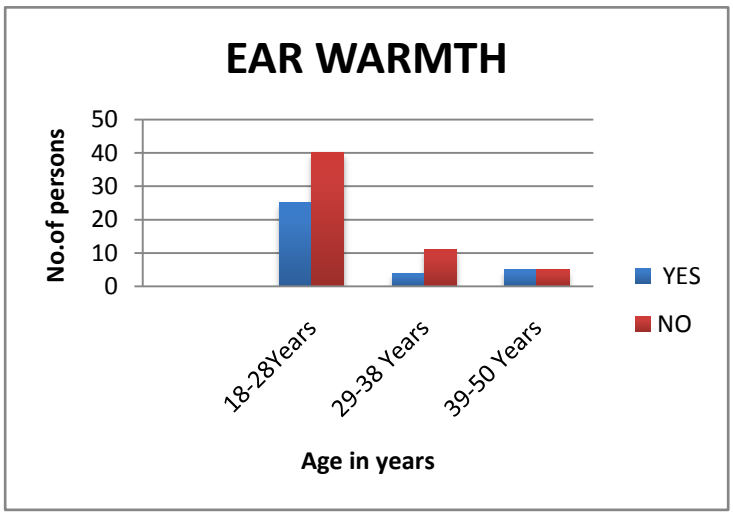
Most of the subjects in the study are in the age group of 18-28 years

AGE DISTRIBUTION BASED ON EAR SYMPTOMS

Age distribution wise subjective ear warmth, ear fullness and tinnitus.

I. Ear warmth

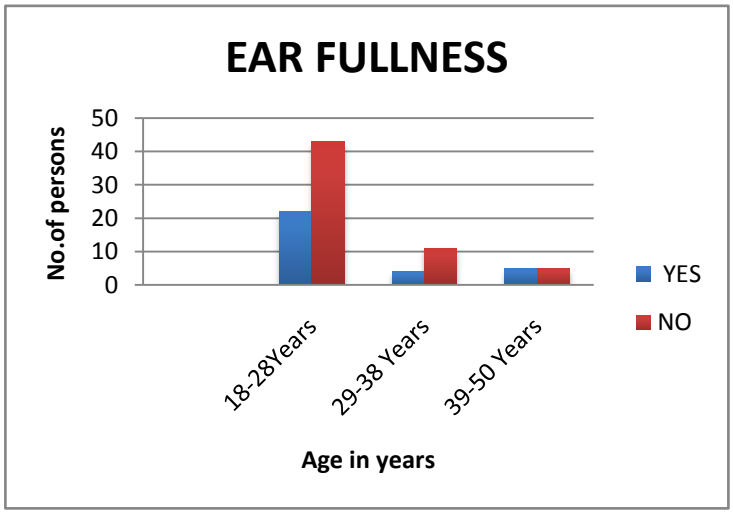
Age (in years)	Ear warmth	
	Yes	No
18-28	25(27.78%)	40(44.44%)
29-38	4(4.44%)	11(12.22%)
39-50	5(5.56%)	5(5.56%)
Total	34(37.78%)	56(62.22%)



Most of the subjects in the study had ear warmth in the age group of 18-28 years

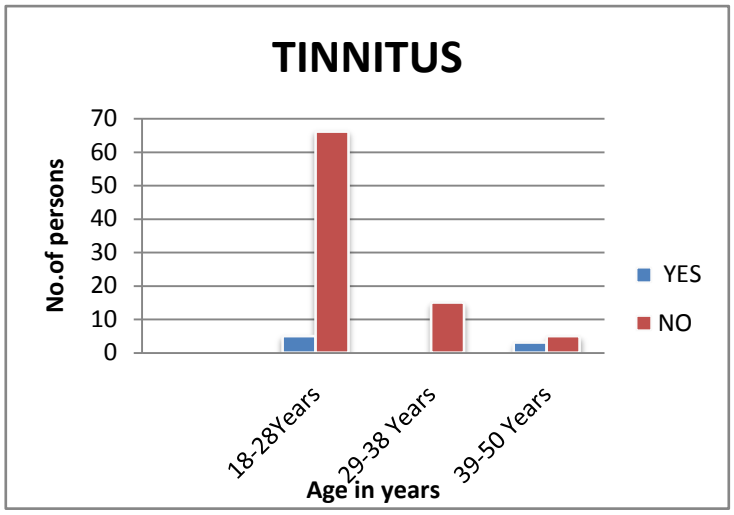
II. Ear fullness

Age (in years)	Ear fullness	
	Yes	No
18-28	22(24.44%)	43(47.78%)
29-38	4(4.44%)	11(12.22%)
39-50	5(5.56%)	5(5.56%)
Total	31(34.44%)	59(65.56%)



III. Tinnitus

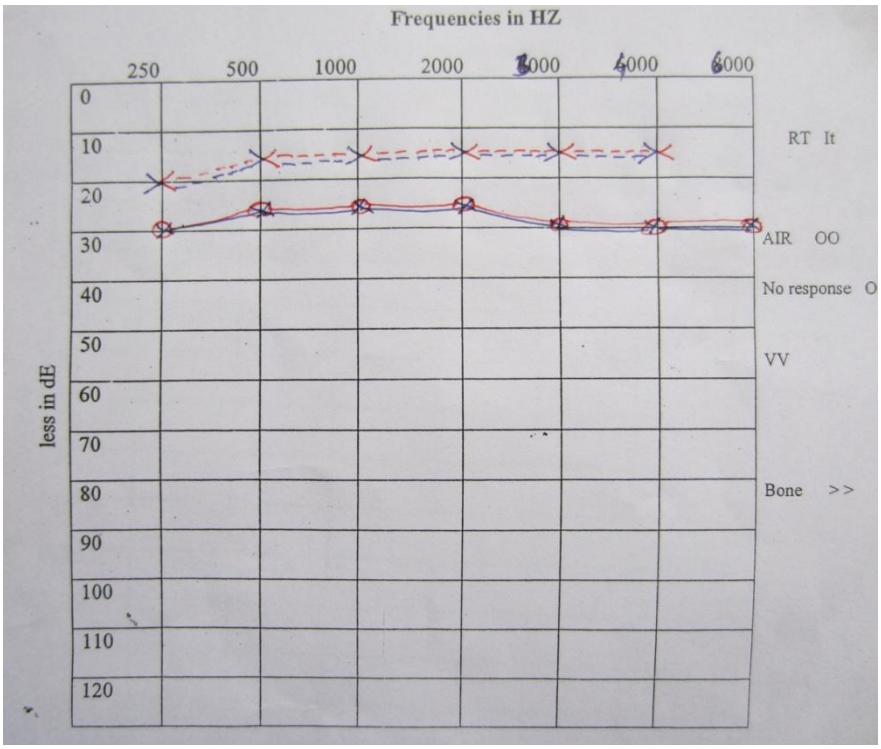
Age (in years)	Tinnitus	
	Yes	No
18-28	5(5.55%)	60(66.67%)
29-38	0	15(16.69%)
39-50	3(3.33%)	7(7.78%)
Total	8(8.88%)	72(91.12%)



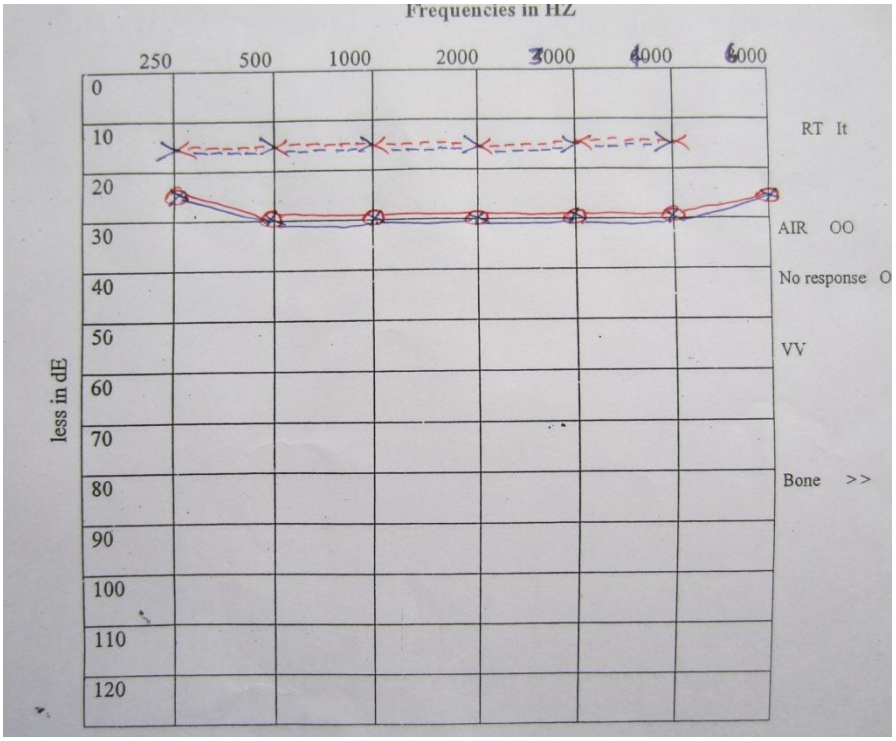
Pure tone audiometry

Model audiograms for a candidate followed for three years. All the four audiograms have hearing within normal limits except the fourth audiogram which has mild threshold increase in one or two frequencies.

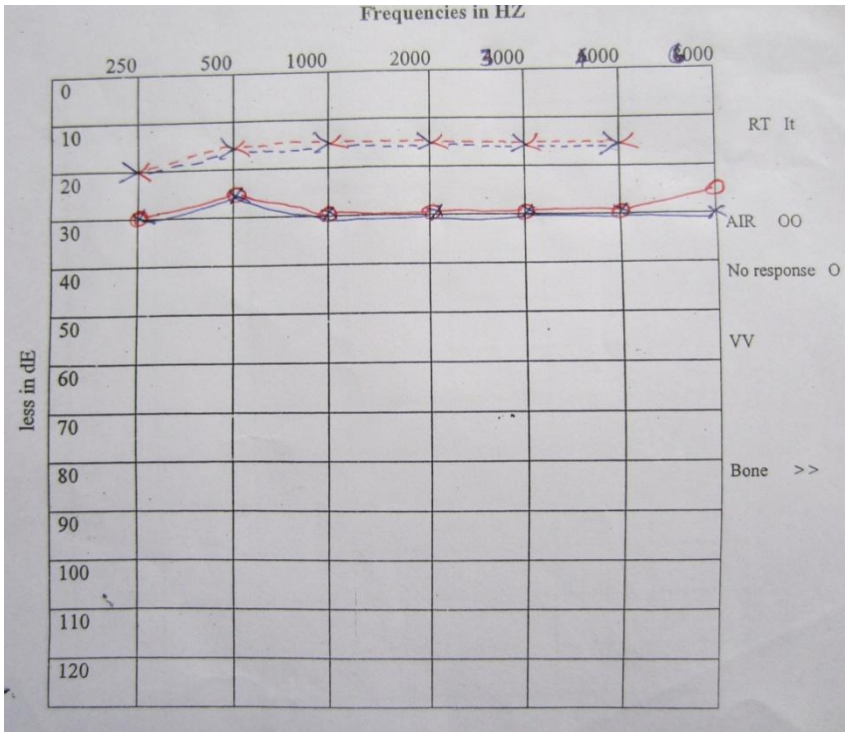
First audiogram



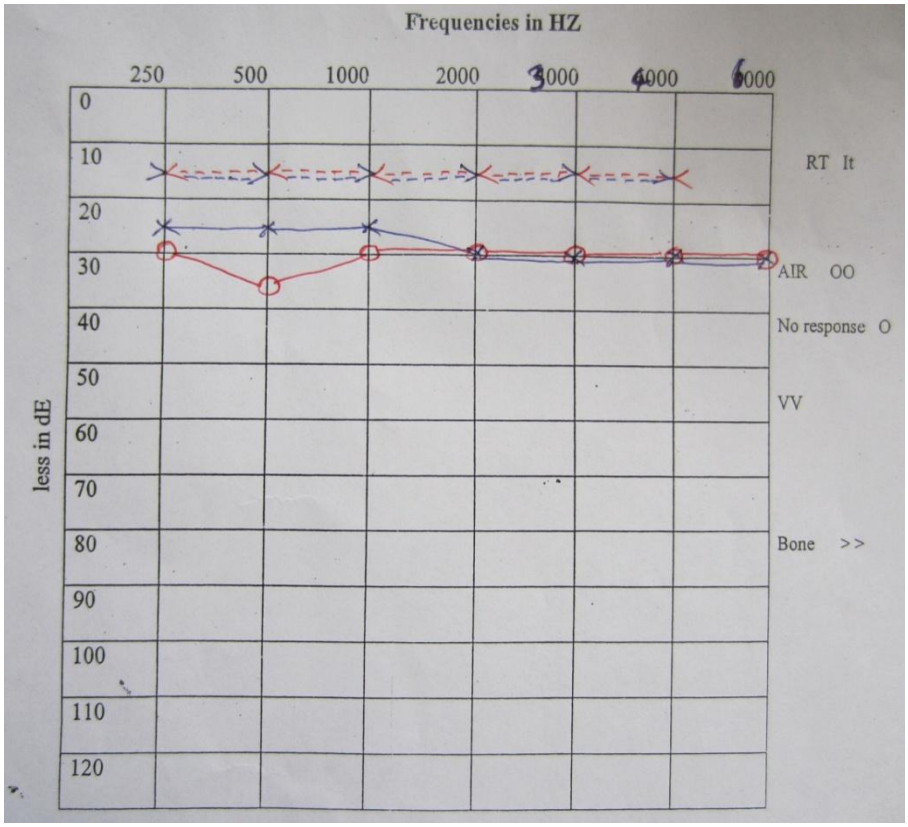
second audiogram



Third audiogram

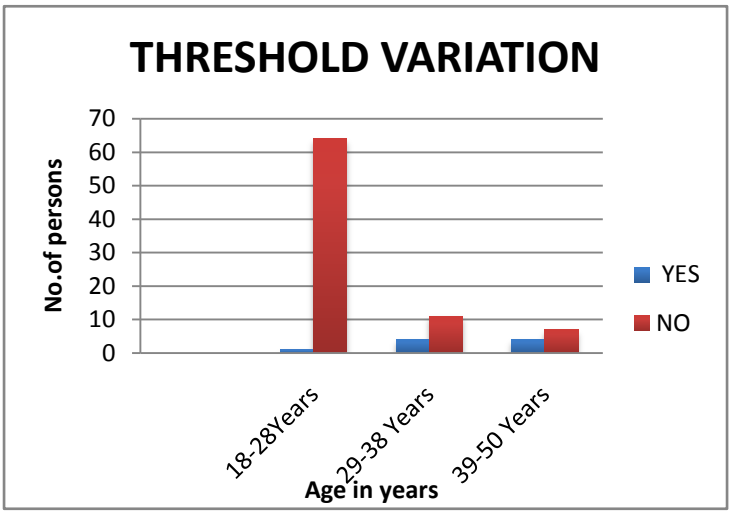


Fourth audiogram



Age versus Threshold variation in one or two frequencies in audiogram

Age (in years)	Threshold variation	
	Yes	No
18-28	1(1.11%)	64(71.11%)
29-38	4(4.44%)	11(12.22%)
39-50	4(4.44%)	6(6.67%)
Total	9(10%)	81(90%)



Threshold variation seen in 4%of the subjects in age group between 29-38 years and also in age group of 39-50.

DISCUSSION

DISCUSSION

Due to rapid increase in the use of mobile phones, particularly in developing countries, even a small effect on health could have significant public health consequences.

As ear is the closest organ to mobile phone this can cause a higher energy deposition in the ear when compared to the other parts of the body, effects of hearing are debated.

A cross sectional study was conducted from a period of November 2010 to October 2012, to study the effects of cell phone use over the auditory system who use their mobile phones for more than half an hour for each call continuously; which was mostly observed in the vegetable traders who use the mobile phones more just before and during trading hours apart from the normal usage than the normal persons. So we planned to do the study among the traders in koyambedu market in Chennai.

We took subject strength of 90and all the subjects were evaluated on Out Patient basis. All the subjects had to fill the

questionnaire which gives a brief history of their ear symptoms on using the mobile phone, past history of any ear discharge or symptoms or surgery.

All the subjects underwent ear examination and ensured that the person is having normal tympanic membrane and external ear canal after removing wax if any.

Subjects who had past history of ear disease, past history of ear surgery with no improvement in hearing, co morbid illness like diabetes mellitus, hypertension, ischemic heart disease, pulmonary tuberculosis were excluded from the study.

In this study all subjects were in the age group between 18 to 50 years. None had past family history of ear disease. Mobile phone usage in our study refers to voice conversation.

All subjects were subjected to pure tone audiometry, which was within the normal limits of hearing except some threshold changes in few frequencies on the final follow up audiogram.

All subjects were in the age group between 18 to 50 years, in which 65/90 (72.22%) are in-between 18 to 28 years of age and 25/90 (28 %) where in-between 29 to 50 years.

In our study 37.78% (34/90) of the subjects have ear warmth in age group between 18 to 50 years, and 62.22% (56/90) did not complain of ear warmth.

Similarly 34.44% (31/90) of subjects complained of ear fullness among the age group between 18 to 50 years and 65.56 % (59/90) did not have this complaint.

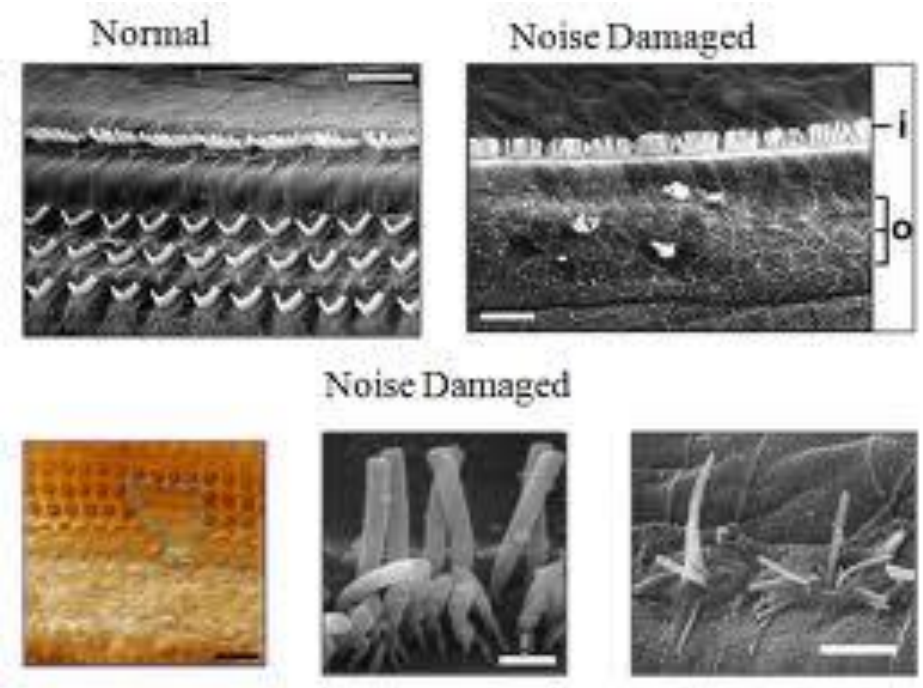
Again 8.88% (8/90) of the subjects have tinnitus and 91.12% (82/90) did not have this complaint.

Hearing assessment was done using pure tone audiogram, on four occasions. The baseline audiometry on the previous day of study, and the second one on the next day immediately after busy working hours.

Third and fourth audiometry was performed in the next two consecutive years after the second audiometry around the same period of the first and second audiometry.

Subjects who had changes in hearing due to other cause (trauma, ear Discharge) during the follow up period were excluded from the study.

On observing the pure tone audiogram on various intervals no significant hearing loss is observed except some threshold changes in one or two frequencies in the final follow up audiogram**.**



Picture showing normal and damaged hair cells

Panda et al conducted a study in 100 people, aged between 18 to 45 years, and grouped them into three categories based on the length of use of mobile phone.

- First group of 35 had been using mobile phone for 1 to 2 years.
- Second group of 35 had been using mobile phone for 2 to 4 years
- Third group of 30 had been using mobile phone for more than 4 years

He concluded that the group who used their mobile phone for more than 4 years had more hearing loss in high frequency ranges in right ear (the ear in which most held the phone) , than who used the mobile phone for 1 or 2 years.

Also he warns that the symptoms like ear warmth or fullness could be the early signs of damage, which we observed in our study.

Oktay et al studied in 2006, concluded that the hearing threshold was seen to be higher for those who use mobile phones greater than 2 hours/day.

Marek Bak et al in 2003 found no correlation was found in hours of usage and hearing loss detected in brainstem evoked response audiogram (BERA)

In studies by Parrizini et al 2007, Ozturan et al 2003, Marek Bak et al 2003, no association was found between ear warmth and excessive mobile phone use.

Since the hearing loss caused by the use of mobile phones is debated, the following recommendations can be taken into consideration in order to minimize the radiation exposure.

1. People having Active medical implants should preferably keep the mobile phone at least 15cm away from the implant.
2. Use mobile phones, when the signal quality is good.
3. Keep your calls short or use short text messages (SMS)
4. Use a wireless –hand free system (Head phone or headsets) with low power Bluetooth emitter.
5. Use the mobile phones which have lowest SAR value, as it reduces the exposure to emitted radiations.

SUMMARY

SUMMARY

The cross sectional study was conducted from a period of November 2010 to October 2012, to study the effects of cellphone usage over the human auditory system.

Total number of subjects – 90 healthy males

All the subjects were in the age group of 18 to 50 years

37.78% (34 / 90) of subjects had ear warmth.

34.44% (31 / 90) of subjects had ear fullness.

8.88% (8 / 90) of subjects had tinnitus

Pure tone audiometry done periodically at the interval of one year from the baseline audiogram showing threshold changes in one or two frequencies in the follow up audiogram in 10% of the subjects**.**

These candidates must be followed up regularly, for a long term to derive a final conclusion.

CONCLUSION

CONCLUSION

In this study, on following up of 90 candidates for 3 years with pure tone audiometry, no significant hearing loss was observed, except some threshold changes in one or two frequencies in the final follow up audiogram.

It is also observed, that the ear symptoms like ear warmth and ear fullness was observed in approximately 30% of subjects and there was no relation between the ear symptoms and threshold changes.

Mild cochlear changes can be revealed in Distortion product otoacoustic emissions and auditory brainstem response.

However this is a small cross sectional study, a large sample and long term follow up will be required to derive definite conclusions.

MASTER CHART

No.	Hospital no.	Sex	Age	Ear warmth	Ear fullness	Tinnitus	Threshold changes in pure tone audiogram without hearing loss
1.	463617	Male	27	Yes	Yes	Yes	Yes
2.	14018	Male	21	Yes	Yes	Yes	No
3.	39833	Male	26	Yes	Yes	Yes	No
4.	50103	Male	20	Yes	Yes	Yes	No
5.	50112	Male	28	Yes	Yes	Yes	No
6.	50106	Male	22	Yes	Yes	No	No
7.	50076	Male	25	Yes	Yes	No	No
8.	50088	Male	22	Yes	Yes	No	No
9.	50085	Male	21	Yes	Yes	No	No
10.	48797	Male	25	Yes	Yes	No	No
11.	50101	Male	22	Yes	Yes	No	No
12.	50108	Male	22	Yes	Yes	No	No
13.	60128	Male	23	Yes	Yes	No	No
14.	60105	Male	22	Yes	Yes	No	No
15.	60115	Male	23	Yes	Yes	No	No
16.	60111	Male	22	Yes	Yes	No	No
17.	60141	Male	21	Yes	Yes	No	No
18.	60133	Male	23	Yes	Yes	No	No
19.	60125	Male	20	Yes	Yes	No	No
20.	60154	Male	25	Yes	Yes	No	No
21.	60108	Male	19	Yes	Yes	No	No
22.	61240	Male	20	Yes	Yes	No	No
23.	61206	Male	22	Yes	No	No	No
24.	61205	Male	22	Yes	No	No	No
25.	61261	Male	20	Yes	No	No	No
26.	61248	Male	22	No	No	No	No
27.	61215	Male	22	No	No	No	No
28.	61211	Male	24	No	No	No	No
29.	61202	Male	27	No	No	No	No
30.	61218	Male	27	No	No	No	No
31.	61251	Male	20	No	No	No	No
32.	61258	Male	19	No	No	No	No
33.	61267	Male	20	No	No	No	No
34.	67245	Male	21	No	No	No	No
35.	83626	Male	26	No	No	No	No
36.	134919	Male	20	No	No	No	No
37.	181274	Male	27	No	No	No	No

38.	168819	Male	25	No	No	No	No
39.	169420	Male	28	No	No	No	No
40.	169436	Male	26	No	No	No	No
41.	184273	Male	24	No	No	No	No
42.	187192	Male	24	No	No	No	No
43.	26371	Male	28	No	No	No	No
44.	005365	Male	19	No	No	No	No
45.	063440	Male	28	No	No	No	No
46.	066880	Male	19	No	No	No	No
47.	066827	Male	22	No	No	No	No
48.	080571	Male	22	No	No	No	No
49.	087674	Male	19	No	No	No	No
50.	106987	Male	24	No	No	No	No
51.	111365	Male	20	No	No	No	No
52.	162251	Male	28	No	No	No	No
53.	177954	Male	23	No	No	No	No
54.	177955	Male	21	No	No	No	No
55.	177956	Male	24	No	No	No	No
56.	316311	Male	24	No	No	No	No
57.	17248	Male	20	No	No	No	No
58.	21936	Male	19	No	No	No	No
59.	220204	Male	22	No	No	No	No
60.	23748	Male	24	No	No	No	No
61.	23254	Male	22	No	No	No	No
62.	254973	Male	19	No	No	No	No
63.	280913	Male	28	No	No	No	No
64.	348535	Male	21	No	No	No	No
65.	348724	Male	21	No	No	No	No
66.	263906	Male	31	Yes	Yes	No	Yes
67.	211874	Male	36	Yes	Yes	No	Yes
68.	69174	Male	34	Yes	Yes	No	Yes
69.	260133	Male	30	Yes	Yes	No	Yes
70.	192828	Male	33	No	No	No	No
71.	180383	Male	30	No	No	No	No
72.	161903	Male	33	No	No	No	No
73.	146343	Male	35	No	No	No	No
74.	119547	Male	38	No	No	No	No
75.	97882	Male	35	No	No	No	No
76.	84038	Male	30	No	No	No	No
77.	75055	Male	34	No	No	No	No
78.	407748	Male	31	No	No	No	No
79.	6531	Male	30	No	No	No	No
80.	067522	Male	38	No	No	No	No
81.	20266	Male	42	Yes	Yes	Yes	Yes
82.	127941	Male	45	Yes	Yes	Yes	Yes
83.	146342	Male	46	Yes	Yes	Yes	Yes

84.	146540	Male	45	Yes	Yes	No	Yes
85.	14537	Male	49.	Yes	Yes	No	No
86.	28307	Male	43	No	No	No	No
87.	106786	Male	39	No	No	No	No
88.	04708	Male	46	No	No	No	No
89.	88983	Male	39	No	No	No	No
90.	172553	Male	44	No	No	No	No

ANNEXURE

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64. ^ http://www.icnirp.org/documents/emfgdl.pdf a whole-body average SAR of 0.4 W/kg has therefore been chosen as the restriction that provides adequate protection for occupational exposure. An additional safety factor of 5 is introduced for exposure of the public, giving an average whole-body SAR limit of 0.08 W/kg.

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