Effects of High Blood Pressure on Hearing Threshold at Different Frequencies and Its Mechanisms in Hypertensive Patients

Nawal B. Ali[1]; Mohamed Abd Al-Ghaffar[2]and Eman A Sabet[3]

[1]Physiology Department, Faculty of Medicine, El Azehar University
[2], Audiology Department, Faculty of Medicine, Sohag Univerisity
[3]Internal Medicine Departments,Faculty of Medicine, Sohag University

Abstract: Aim of the study: This study was carried out to assess the effects of high blood pressure and its associated changes in the form of high fibrinogen level and high plasma atrial natriuretic peptide (ANP) level on hearing threshold in hypertensive patients. In this study, 100 persons (200 ears) 50 males and 50 females, with age range of 50-55 years, took part. They were equally divided into two groups, hypertension group and control group. Hypertension group included hypertensive patients previously diagnosed as hypertensive patients of at least 10 years duration with systolic BP above 140 mmHg and diastolic BP above 90 mmHg. They were under treatment of hypertension. After audiometry, the hypertension group was divided into two subgroups according to hearing threshold, the first subgroup contained hypertensive patients with hearing threshold less than 25 dB(with no hearing loss) and the second subgroup contained hypertensive patients with hearing threshold above 25 dB(affected with hearing loss). Control group contained normtensive persons with systolic blood pressure and diastolic blood pressure less than 140 mmHg and 90 mmHg respectively. Blood pressure (Systolic, diastolic and mean), pure tone audiometry at different frequencies, plasma fibrinogen level, and plasma ANP level, were measured. **Results:-** The results indicated that: 1- There is highly significant ($p<0.001$) increase in hearing thresholds (worse hearing) at all high frequencies in hypertensive patients. The highest hearing threshold was recorded at 8000 Hz-frequency.2- There is an increase in percentage ratio of persons affected with hearing impairment at 2000, 4000 and 8000 Hz frequency separately (hearing threshold above 25 dB) in hypertensive patients on comparison with control group. The highest percentage ratio of persons with hearing deterioration at certain frequency is at 8000 Hz–frequency. It may be an indicator of beginning of hearing impairment in hypertensive patients. 3- There is an increase in percentage ratio of persons affected with high-frequency hearing impairment (mean hearing threshold in all high frequencies collectively in the same person above 25 dB) associated with high blood pressure It arrived to 84% in hypertensive patients instead of 22% in controls. High blood pressure leads to increase in number of affected persons with high-frequencies hearing impairment to about 4 times as in controls. 4- High blood pressure is associated with highly significant ($p <0.001$) high fibrinogen level. That level is positively correlated with hearing threshold at all high frequencies, and positively correlated with hearing threshold separately at 8000 Hz-frequency.5- High blood pressure is associated also with highly significant ($p <0.001$) elevated plasma ANP level. ANP level is positively correlated with, mean blood pressure, hearing threshold at all high frequencies, and at hearing threshold of 8000 Hz-frequency. 6- In hypertensive patients who affected with high frequency hearing loss, there is significant ($p < 0.05$) increase of plasma fibrinogen level and plasma ANP level compared with hypertensive patients without hearing loss. **Conclusion:** High blood pressure is a risk factor for high-frequency hearing impairment. Hypertension is also associated with increase percentage ratio of persons affected with high-frequency hearing impairment. 8000 Hz-frequency is the most affected frequency in hypertensive persons, and may be an indicator for start of hearing impairment in them. High plasma fibrinogen level and high plasma ANP level, that are associated with high blood pressure, are directly related to deterioration of hearing threshold in hypertensive patients. The role of fibrinogen and ANP in pathogenesis of hearing loss in hypertensive patients must be thoroughly investigated. Also extended high frequency audiometry is highly recommended for early detection of hearing loss in hypertensive patients.

[Nawal B. Ali; Mohamed Abd Elgfar and Eman A Thabet. **Effects of High Blood Pressure on Hearing Threshold at Different Frequencies and Its Mechanisms in Hypertensive Patients.** *J Am Sci* 2012;8(12):618-629]. (ISSN: 1545-1003). http://www.jofamericanscience.org. 85

Keywords: High blood pressure ,hearing threshold, HL, ANP level, fibrinogen level.

1. Introduction:

Systemic arterial hypertension is one of the most common cardiovascular diseases. The relevance of arterial hypertension as a human disease is due to clinical complications, morbidity, and mortality, as well as the burden to the patient, family, and public coffers. Few diseases are responsible for so frequent and severe complications as the ones occurring from arterial hypertension: cerebro-vascular stroke, heart, kidney and peripheral vascular insufficiencies. Moreover, it is estimated that about half of the deaths of patients above 50 years are due to cardiovascular

diseases, and 80% of them have high blood pressure. Cardiovascular diseases and hearing loss are both highly prevalent among older adults (**1**). Hypertension is associated with hearing symptoms e.g. hearing loss and tinnitus (**2).** Studies in animals have suggested a connection between arterial hypertension and hearing loss (**3**). Many studies support that hypertension is considered as an important risk factor in many pathological process, including hearing loss (**2).** It seems apparent that there is a correlation between hypertension and hearing loss, but it has not been established that there is a causal relationship between these two entities, the association is most likely a complex one. Different forms of hypertension may have different etiologies (**2,4, 5**). Experimental studies tend to factor the concept parallel events rather than direct effect of hypertension on the cochlear function (**6**). On the other hand, many other studies did not relate hypertension to hearing loss (**7, 8**). The studies that prove hypertension as a risk factor for hearing loss differ in the type of affected frequencies. Some confirm high frequencies affection (**3**). Other studies showed association of hearing loss for speech frequencies in hypertensive patients (**6**).

The role of increase in fibrinogen level associated with hypertension and hormonal change in the form of elevated plasma **ANP** level, and their relations to hearing loss were debate and less discussed (**9**).

This Study Aims To Identify:-

a) The Effects Of High Blood Pressure On Hearing Thresholds At Different Frequencies In Hypertensive Patients.
b) Relation Of Hypertension Associated Changes In The Form Of High Plasma Fibrinogen Level And High Plasma ANP Level With, Hearing Threshold At Different Frequencies, Deterioration Of Hearing, And Its Mechanisms.

Because hypertension is a major public problem, in view of the result it is possible that early diagnosis of hypertension, way of treatment, will benefit a significant number of people who would otherwise lose their hearing with advanced age.

2. Subjects and Methods

Subjects

One hundred persons (200 ears), 50 males and 50 females, with age range of 50-55 years, were equally divided into hypertension group and control group.

1-Hypertension Group:-

This group included hypertensive patients from Sohage University, Internal Medicine Clinic, in the period from September 2009 to December 2011. All patients were previously diagnosed as hypertensive patients of more than 10 years duration with Systolic BP above 140 mmHg and diastolic BP above 90 mmHg (**1**).The hypertensive patients were under treatment. After audiometry, according to hearing threshold level, they were divided into two subgroups. The first subgroup contained eight hypertensive patients, five males and three females with hearing threshold at all high frequencies (2000, 4000,and 8000) collectively below 25 dB. The second subgroup was consisted of forty- two hypertensive patients, twenty-seven males and fifteen females, with hearing threshold level above 25 dB (affected with hearing loss).

2-Control Group:-

Normotensive persons with systolic blood pressure less than 140 mmHg and diastolic blood pressure less than 90 mmHg, were included in the control group.

All persons in hypertension group or control group were of average body built, and were chosen nearly with the same circumstances as regard economic and living states. The included persons either from the hypertension group or control group had:-

1-A questionnaire was constructed covering a variety of items about personal and medical histories, medication use (antihypertensive, ototoxic drugs) and habit of daily living (smoking, alcohol consumption, muscular exercise, exposure to noise for long periods and use of hearing aids). Any person were excluded if he or she had history of diabetes, coronary heart diseases, history of repeated ear troubles, head injury, intake of ototoxic drugs, and exposure to noise for long periods.

2-Informed consents from the persons were taken; including clearance for use of examination data were done.

3-General examination

Meticulous general examination was done with special attention to:

Blood pressure that was measured three times at different times and finally the mean of the three measures was taken. Systolic and diastolic pressures were recorded and the mean arterial blood pressure was calculated from the following formula(10):

Mean blood pressure in mmHg = { diastolic blood pressure +0.333(systolic blood pressure - diastolic blood pressure)} .

The patient is considered as hypertensive patient from the history of anti hypertensive treatment intake (1) and the follow up card in internal Medicine Clinic.

Heart for signs of heart failure (congested neck veins-enlarged liver-edema of lower limb).

Liver for manifestations of liver cell failure (jaundice -tremors-manifestations of hypo-proteinemia e.g. edema &bleeding tendency).

Kidney for manifestations of renal failure (manifestations of uremia).

4- Local examination

Otoscopic examination was done for both ears. External ear, middle ears, Nose, and throat were locally examined.

5-Investigations

a-Special investigations

- **1-Audiometry: 1-Audiometry and Immittancemetry:** All ears that passed otoscopic examination, Basic audiological evaluation including pure tone and speech audiometry using a computerized two channel audiometer Amplaid model 309 in sound treated room IAC model 1602, and acoustic immittance testing (tympanometry, acoustic reflex threshold measurement), using Immittancemeter Amplaid model 775. Threshold was considered the lowest hearing level at which responses occurred for at least half of series of ascending trials with minimum of two responses out of three presentations at a single level. Audiometry was done for each ear, either right or left and After hearing thresholds estimation for standard audiometric frequencies in each ear were done, the mean for both ears at each frequency was taken, The mean hearing threshold at all low frequencies in the same person was calculated and the mean for all high frequencies also was calculated (**13**). Hearing loss is defined when the hearing threshold averages are above 25dB at any frequency (**11**).

2- Estimation of plasma fibrinogen level

3-Estimation of plasma ANP peptide Level

b- General investigations

The following investigations were done for each person in this study:

-ECG (model CARDIPIA 200**)**

-Blood sugar (fasting and post prandial **)**

-Kidney function tests (urea and creatinin **)**

-Bleeding time and coagulation time

Each person with any of the following manifestations was excluded

Manifestation of cardiac ischemia in ECG, fasting blood glucose above 90 mg/dl, post prandial blood glucose above 140 mg/dl, urea more than 40 gm/dl, creatinin more than 40 mg/dl, bleeding time above 6 minutes, and coagulation time above 8 minutes(**10**)

Sampling:

Blood samples were collected at about 12 p.m. by a chilled Syringe and each sample was divided into two specimens. Each specimen was transformed into poly propylene tube. One tube contained EDTA (mg/ml) for ANP estimation and the second contained 0.1 M sodium citrate for fibrinogen level estimation. Samples were stored at -80°C till time of investigation. **Fibrinogen** level was estimated in plasma by Assay Max Human Fibrinogen (FBG) ELISA Kits supplied by Gentaur Company, USA**. ANP** level was estimated by using enzyme- immunoassay technique. This assay employed a quantitative competitive enzyme immune assay technique which was availed with the kit used for ANP estimation of Uscnk Company.

Statistical analysis

Data were collected and analyzed by computer program SPSS (ver.17) Chicago. USA. Data expressed as mean ± Standard Errors (SE), and percentage of change. Using, Student "t" test to determine significant for numeric variable, Chi. Square to determine significant for non–parametric variable, person correlation for numeric variable in the same group, $P > 0.05$ is not significant.

3. Results

Table (1): Shows the mean values of blood pressure (systolic, diastolic, and mean BP) for hypertension group and control group.

Effects of high blood pressure on hearing threshold at different frequencies.

Table (2) and Figs (1): Show that in hypertension group, there is highly significant ($p< 0.001$) increase of hearing threshold "worse hearing" at all high frequencies with increase percentage of 57% versus control group. Maximum increase percentage is at 8000 Hz-frequency (130%). On the other hand, at low frequencies there is significant increase at 250 Hz frequency ($P<0.05$) and insignificant change is present at 500 Hz,1000 Hz frequencies, so insignificant increase in mean hearing threshold level at all low frequencies was observed.

Hearing deterioration in hypertensive patients affects the high frequencies. Hypertension is a very important risk factor for high frequency- hearing loss.

Table (3): Shows the percentage ratio of persons who have hearing impairment at different frequencies (hearing threshold > 25 dB). Affection with hearing impairment is more predominant in hypertension group than in Controls. In hypertension group, the highest percentage ratio of affected persons was recorded at 8000 Hz – frequency (100%) followed by 4000 Hz – frequency (40%), then 2000 Hz-frequency (22 %). But in Controls, 4000 Hz-frequency, is the most affected one (30%) followed by 8000 Hz-frequency (24%).

Percentage ratio of persons with hearing impairment at 8000 Hz in hypertension group is four times as in controls that indicate the role of high blood pressure in deterioration of hearing especially at 8000 Hz-frequencies.

Fig (2): Shows the percentage ratio of persons affected with high -frequencies hearing loss (mean hearing threshold for all high frequencies collectively for the same person > 25 dB). In hypertension group, percentage ratio of persons affected with hearing loss is 84%, but in Controls it is 22%.

Hearing loss in hypertension group is about **four times as in Controls.**

Fibrinogen level and hearing threshold.

Table (4) and *Figs (3a, b)*: Show that there is highly significant (*P*<0.001) increase in fibrinogen level in hypertension group compared with control group (percentage ratio of increase is 52.17%). This increase in fibrinogen level is positively correlated with hearing threshold at all high frequencies and with hearing threshold at 8000 Hz-frequency, with correlation coefficient of 0.4. It is obvious that hypertension is associated with high fibrinogen level.

Table(5) and Fig(3c): Show significant (P < 0.05) increase in mean plasma fibrinogen level in hearing loss-affected subgroup of hypertension group versus non affected one. Difference between mean mean blood pressure values in both subgroups were insignificant.

The deterioration of hearing threshold in hypertensive patients may be caused by the increase in fibrinogen level not the high blood pressure. with possible role of high plasma fibrinogen level in pathogenesis of hearing loss in hypertensive patients.

Atrial natriuretic peptide plasma level, and hearing threshold.

Table (4) and Figs (4a-c): show that there is highly significant (P <0.001) increase of mean ANP plasma level in hypertension group compared with control group with increase percentage ratio of 35.35%. ANP level hypertension group is positively correlated with mean blood pressure (correlation coefficient is of 0.5). Hearing threshold at all high frequencies and at 8000 Hz-frequency are also positively correlated with plasma ANP level with correlation coefficient of 0.6 and 0.5 respectively.

Table (5), and Fig (4d): show significant (p < 0.05) increase in mean plasma ANP level, and insignificant increase in mean blood pressure in hearing loss-affected subgroup of hypertension group versus the non affected subgroup.

High plasma ANP level which associated with high blood pressure may share in hearing deterioration process in hypertensive patients not high blood pressure.

Table (1): Mean values of arterial blood pressure (mmHg) in control group and hypertension group.

	Systolic pressure		**Diastolic pressure**		**Mean pressure**	
	Control group	**Hypertension group**	**Control group**	**Hypertension group**	**Control group**	**Hypertension group**
Mean	126	195.5	83.6	114	97.71	141.13
±	±	±	±	±	±	±
SE	1.02	0.74	0.97	0.89	0.93	0.78
P values vs. controls		●●●		●●●		●●●
% of Increase		55.15		36.36		44.43

SE= Standard Error vs. = versus ●●● = Significant at P < 0.001 % =percentage ratio

Table (2) Mean hearing threshold in dB at different frequencies in hypertension group and control group.

	Frequency in HZ	250	500	1000	All low frequencies	2000	4000	8000	All high frequencies
Hypertension Group	Mean	10.5	12.5	10.1	11.13	23.5	25.5	46.3	30.37
	±	±	±	±	±	±	±	±	±
	SE	0.57	0.65	0.83	0.61	0.60	0.62	0.39	0.47
	P values vs controls.	•	NS	NS	NS	●●●	●●●	●●●	●●●
	Percentage of change	20.6%↑	5.8%↑	10.6%↓	3.8%↑	38%↑	29%↑	130%↑	57%↑
Control Group	Mean	8.7	12.1	11.3	10.7	17	19.7	20.1	19.3
	±	±	±	±	±	±	±	±	±
	SE	0.51	0.56	0.73	0.51	0.68	0.91	0.89	0.62

SE= Standard Error • Significant at P< 0.05 ↓ = Decrease NS = not significant

vs = versus. ●●● =Significant at p< o.oo1 ↑ = Increase

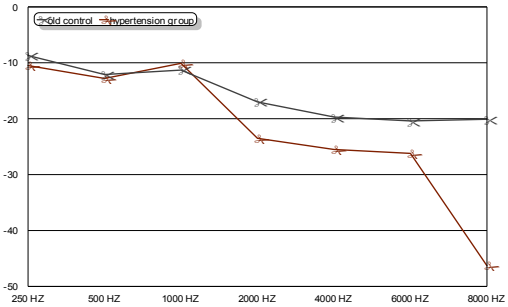


Fig (1): Hearing thresholds at different frequencies in hypertension group and control group

Table(3):Percentage ratio of persons with hearing impairment at different frequencies (Hearing threshold above 25 dB) for control group and hypertension group

Group / Frequency in Hz	Control group	Hypertension group
250	–	–
500	–	–
1000	–	–
2000	–	22%
4000	30%	40%
8000	24%	100%

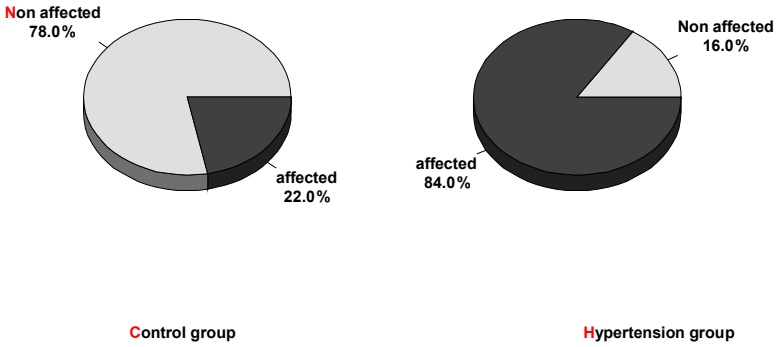


Fig (2): Percentage ratio of persons affected with hearing loss (Mean hearing threshold at all high frequencies collectively >25dB) in hypertension group and control group

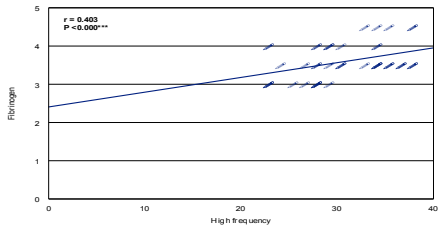


Fig (3a): Correlation between mean hearing threshold at all high frequencies and plasma fibrinogen level in hypertension group

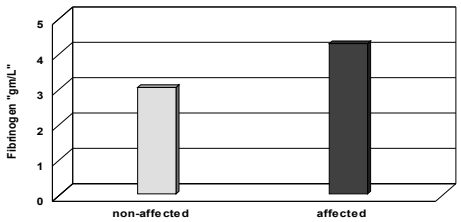


Fig (3c): Plasma fibrinogen level in hypertensive patients, affected, and non affected with hearing loss

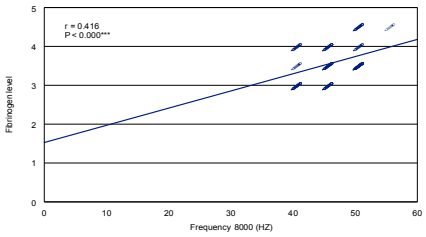
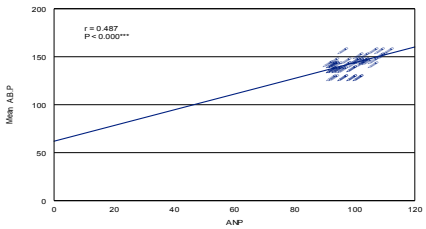


Fig (3b): Correlation between plasma fibrinogen level and hearing threshold at 8000 HZ- frequency in hypertension group



Fig(4a): Correlations between plasma ANP level, and mean arterialblood pressure in hypertension group

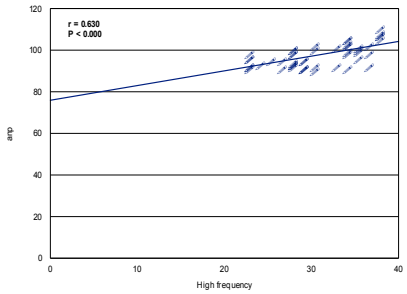


Fig (4b): Correlation between ANP level and hearing threshold at all high frequencies in hypertension group

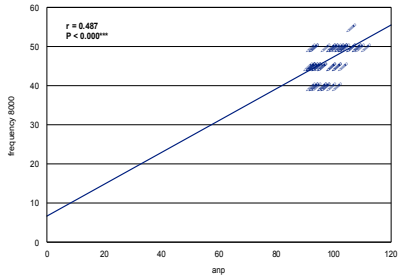


Fig (4c): Correlations between plasma ANP level and hearing threshold at 8000 Hz-frequency in hypertension group

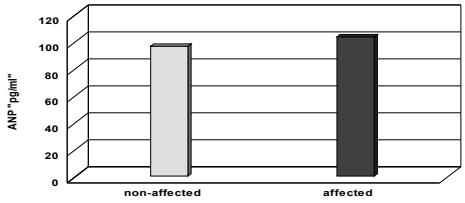


Fig (4d): Plasma ANP level in hypertensive patients, affected and ± non affected, with hearing loss

Table (4): Mean plasma fibrinogen level and ANP level for control group and hypertension group

	Control Group (M+SE)	Hypertension Group (M+SE)
Fibrinogen level		
Mean ± SE	2.30 ± 0.013	3.5 ± 0.045
***P* values vs. control group**		●●●
% of Increase		52.17
ANP level		
Mean ± SE	71.96 ± 0.28	97.4 ± 0.75
***P* values vs. control group**		●●●
% of Increase		35.35

SE= Standard Error ●●● =Significant at $P < 0.001$. vs. = versus. **%** =Percentage

Table (5): Comparison between hearing loss affected and non affected subgroups of hypertension group.

Variable	Non affected sub- group	Affected with HL Sub-group	*P* Values
2- Mean hearing threshold	22.67±0.121	31.62 ± 0.414	***
3- Mean mean blood pressure	135.31± 0.642	143.23 ±0.688	NS
Plasma fibrinogen	3.35±0.122	3.61±0.04	*
Plasma ANP level	94±1.00	97.99±0.83	*

*P value < 0.05 SE= Standard error
*** P value <0.001 HL= hearing loss
ANP= Atrial Natrinretic peptide
NS=Not significant

4.Discussion

Hypertension is a path-physiological concomitant of aging that seems to be an important risk factor for hearing loss. Hypertension has been associated with hearing symptoms e.g. tinnitus (**14**). Many studies suggested a connection between arterial hypertension and hearing loss (**15**).

In the present study, the effects of hypertension in old age on hearing threshold at different frequencies were examined; the associated changes with hypertension in the form of fibrinogen level and level of ANP and their relation to hearing threshold were examined also.

1-Effects of high blood pressure on hearing

Results of the present study revealed that

-High blood pressure lead to deterioration of Hearing i.e. increase in hearing threshold that affect all high frequencies. So that, high blood pressure is a risk factor for high frequency- hearing loss in old age.

-High blood pressure is not only associated with increase hearing threshold at high frequencies but associated also with increase percentage ratio of persons affected by high- frequencies hearing loss about four times as controls.

The results of this study are in accordance with many studies either experimental or clinical. Li Sui research on Spontaneous Hypertensive Rats Species had demonstrated that hypertension was the risk factor of hearing loss(**2**). Safar and Frohlich concluded that long term hypertension resulting in abnormal accommodation of hearing and finally damaging the hearing (**16**). Ma Kishima found positive relation for hearing loss and hypertension in older adults(**17**). Fang supported that age related hearing loss might be accelerated by hypertension (**18**). Kathleen hypothesized that healthy CV system attenuates the effect of age on hearing process(**19**).

Sheila, Karamitsos and Parving are not with this results as they reported that the lack of cardiac vascular diseases influence on hearing sensitivity (**11,20,21)**. It is possible that lack of CVD effect might relate to the composite and mixed nature of subclinical and clinical CVD as defined in their study.

-The results that recorded in this study found that mean blood pressure is not correlated with Hearing threshold at all high frequencies in old hypertensive patients.

Rosenhall, Study concluded that animals with induced hypertension showed no correlation between hearing loss and systolic blood pressure. Pyykko study found no correlation between systolic blood pressure and hearing loss in human (**6**).

This result differs with Raymond (**22**). They found that there is 32% greater risk of developing hearing loss for every 20- mmHg increase in systolic pressure. Brant found that systolic blood pressure showed significant relationship with hearing loss (**23)**. Also Elizabeth Study found that higher diastolic blood pressure is associated with hearing loss (**24**).This may be explained by wide range of blood pressure in their study and longer duration of hypertension.

-It is clear from this study results that 8000 Hz – frequency is the most affected frequency in hypertensive patients. The highest hearing threshold and the highest percentage ratio of persons affected with hearing deterioration are at 8000 Hz-frequency.

This study results are in accordance with Esparza et al who found that there is an increase in hearing threshold at 8000 Hz frequency in hypertensive patients (**15**). Hearing loss of vascular cause lead to cochlear ischemia that could lead to reduction of endocochlear potential and that could affect all turns of the cochlea and so CVD is associated with high frequency-hearing loss is reasonable (**25**). Kogak in their animal study found that in ischemia related dysfunction, there is sporadic fusion of hair cells ten days after ischemia, the mean percentage cell loss of inner hair cells, was 6.4% in the basal turn, and 0.8% in apical turn and member of spiral ganglion cell neurons decreased to 89% of pre-ischemic status**(26)**.

On the other hand, this study results are not with Rosenhall and Valtes who found that there is correlation between high blood pressure and hearing loss in low and mid frequencies in elderly women of 79 year-old and 85-year-old women(**6**). That may explained by older age patients than in this study and also the female patient affected by hormonal changes there is gender differences in progress of cardiovascular diseases and hearing loss and differences in hearing sensitivity that may be hormone dependent (**24**).

2- ***Plasma Fibrinogen level and hearing threshold***

In this study it was found that High blood pressure is associated with elevated fibrinogen level. Fibrinogen level was positively correlated with hearing threshold at all high frequencies and also positively correlated with hearing threshold at 8000 Hz-frequency. Higher level of plasma fibrinogen is present in hypertensive patients affected with hearing loss compared with hypertensive patients without hearing loss.

The present study agree with many studies e.g. Carrasco and Gates who justified the hearing loss that happens with aging is related to a microcirculatory insufficiency that occurs due to vascular occlusion caused by emboli and this happen because of syndrome of hyper viscosity caused by hypertension (**25,26**). Zhang concluded that elevated plasma fibrinogen may be a major pathogenesis in hearing loss (**27**). Also Minka found that oxygenation of the cochlear structures was decreased by perfusing the ears with polycythemic hyper viscous blood in guinea pigs (**28**). Heigl stated that sensory neural hearing loss may be caused by reduction in cochlear perfusion. Fibrinogen negatively influences rheological properties of blood thus leading to alternation of microcirculation (**29**). Elizabeth found that current salcylates use and chronic use were associated with lower odds of hearing loss, perhaps due to cardioprotective effect of salicylate and its anticoagulation effect(**4**). Increase in blood viscosity which reduce capillary blood flow and ends up reducing O_2 transport causing tissue hypoxia thus leading to hearing loss(**1**). It was found that blood viscosity can affect cochlear action potentials and oxygenation that by, they perfused the ears of guinea pigs with polycythemic hyperviscous blood to vertebral artery lead to decrease rate of flow of blood through cochlear vessels. Hyper viscous blood were associated with reduced Po_2 in scala media to 53.3% of normal (**28**). Elevated plasma fibrinogen may lead to elevated plasma viscosity lead to hyper coagulability state which impairs cochlear perfusion (**30**). Hypertension is associated with virchow's triad for thrombogenesis is leads to hypercoagulability state due to change platelet endothelium and fibrinolytic pathway (**31**).

3-Plasma ANP level and hearing threshold

-The present study revealed elevation in the level of ANP in hypertensive patients. This elevation is positively correlated with mean arterial blood pressure, hearing threshold at all high frequencies, and hearing threshold at 8000 Hz-frequency. Hypertensive patients affected with hearing loss have higher ANP level.

These results agree with Mc Cormick who said that ANP may be one of the direct causes of hypertension-related hearing loss. ANP is present in blood of hypertensive patients and animals; it may be the cause of many forms of hypertension. Battar and

Mc Cormick said that preliminary results in their laboratory indicate that natriuretic hormone sample can suppress the cochlear potential in guinea pigs which leads to hearing loss(**32**). Oiao concluded that ANP regulate blood pressure and could play an important role in modulating of microenvironment of inner ear **(33)**. Receptors of ANP in inner ear has been widely reported in studies concerning both rat and human inner ear (**34**). Arterial high pressure may cause ionic changes in cell potential lead to hearing loss (**1**). With aging, the hypertensive animal had a higher electrochemical potential happen only in extremely aged animal while potassium concentration increase not only in endolymphatic cells but also in perilymphatic one, ANP hormone may cause sensory neural hearing loss by inhibiting sodium/potassium pump of the stria vascularis of inner ear, Also ANP may cause hypoxia of stria vascularis or the sensory hair cells. or both by increasing vascular reactivity of the arterioles supplying inner ear (**9**).

All living cells in the human body depend on a proper supply of oxygen and nutrients in order to maintain their functions, and such supply depend on the functional and structural integrity of the heart and blood vessels. Hypertension, the most common vascular disorder, may facilitate structural changes in the heart and blood vessels (**35**). The mechanisms that cause degeneration of hearing apparatus are caused by circulatory problems most specifically caused by high blood pressure (**1**). These are several pathophysiological parameters related to hypertension that may potentially depress the inner ear performance.

Cochlear potential maximum intensity function is highly correlated with number of viable sensory hair cells in inner ear (**9, 36,37**). Normally functioning cochlear microcirculation is critically important for maintaining endocochlear potential, ions, fluid balance in inner ear and in preventing toxic substances from entering cochlea because hair cells are strikingly vulnerable to ischemia (**38,39**). Animal models provided fundamental information about the relation between cochlear blood flow and cochlear structural integrity (**40**). The ostria uses much of metabolic energy in maintaining endocochlear potential. This energy transformation in cochlea allows for auditory sensory function to occur and this is one of the first steps in hearing (**41**). The cochlea is principally supplied from the inner ear artery, terminating spiral modiolar artery which is a branch of ant. inf. Cerebellar artery. Cochlear blood flow is a function of cochlear perfusion pressure, which is calculated as the difference between mean arterial blood pressure and inner ear fluid pressure "peri lymphatic and endolymphatic"(**41**).

Any degeneration in the stria vascularis affects the quality of endolymph causing disruption of physical and chemical processes by which energy is created in Organ of Corti . If the blood supply to cochlea is not constantly replenished the health of system become vulnerable (**41**). Lawrence has discovered a direct metablic dependence of sensory hair cells on microcirculation bed in the inner ear: The vas- spirale, such system potentially could be influenced by change in systemic blood pressure, related to alternation in cochlear blood flow (**42**). It was found a positive correlation between cochlear potential and blood pressure (**43**). Sound stimulation of inner ear imposes an energy demand. A well regulated cochlear blood flow is needed to meet this requirement. Auto regulation of cochlear blood flow has been demonstrated in some animal models in viva, suggesting that similar to brain, blood vessels supplying the cochlea have the ability to control flow within normal limits, despite variations in systemic blood pressure(**44**). Regulation of cochlear blood flow is hypothesized to include both local auto-regulatory and central control through neural pathway(**38**). Contraction of smooth muscle cells in spiral modiolar artery is hypothesized to be tightly regulated to meet the demand of cochlear tissues(**39**). Sympathetic adrenergic nerve fibers have been found in spiral modiolar artery of gerbil and guinea pig (**45,46**).

Inner ear circulation has at its disposal a marked ability of auto-regulation, its microcirculation correlates with aortic pressures, decrease in blood pressure, sympathetic stimulation leads to decrease and sympathectomy lead to increase cochlear circulation (**47**). Nor epinephrine-induced vascorstriction in the spiral modiolar artery is mediated ly α1A-adrenergic receptors (**48**). Stimulation applied in the sympathetic ganglia, stellate ganglion, or sup cervical chain in the guinea pig has been shown to alter Cochlear blood flow in situ (**49- 51**). These findings support hypothesis that Co BF is controlled by neuronal signals at the level of the spiral modiolar artery (**52,53**). On the other hand, capillary mediated local control of perfusion was first reported **(54).** The pericytes express contractile proteins α smooth muscle actin and tropomyosin exhibit vasocontractility under both in vivo and in vitro conditions(**55**).The contractility of pericytes could affect flow resistance of vascular network and may profoundly alter the overall blood (**38**). CoB F is regulated by multiple metabolic factors e.g nitric oxide and prostaglandin. Degoute reported that sympathetic nerve regulation via its vasomotor tone at the level of cochlear microcirculation occurred markedly when blood pressure was above 160 mmHg and that the autonomic nervous system appeared to control cochlear blood flow against larger variation in blood flow in response to hypertensive phenomenon (**56**).

Seidman said that age is associated with state of low blood flow and stasis decrease in cochlear blood leads to decrease in auditory sensitivity (**57**) . It was found that decrease in blood flow in older animals was clearly not related to loss of strial capillaries with aging (**58**). The decrease flow to lateral portion must arise from either decrease perfusion pressure or from increased vascular resistance. This dedcrease in blood flow support vascular theory. Brown observed that cochalear vascular reactivity was less in old mice than in young mice **(59)**.

Hypertension is a risk factor of degeneration of hearing apparatus **(27)**. An electron microscopy study demonstrated that the primary site of involvement of hypertension within the cochlea is the stria vascularis followed by Organ of Corti **(14)**. It was suggested that cardiovascular disease may result in hearing loss by causing reduced vascular supply to the cochlea **(60).** A positive relation has been reported for hearing loss and (a) degree of internal auditory artery steno sis. (b) The degree of spiral ganglion atrophy based on histological studies of temporal bones and brain sections from older adults with hypertension **(17)**.

Fang study suggested that progress of vessel change in patients with age related hearing loss might be accelerated by atherosclerosis and hypertension. Atherosclerosis has been hypothesized to cause reduced blood flow to the cochlea via stiffening or constriction of internal auditory artery **(18)**. Insufficient cochlear blood supply can disrupt chemical balance of inner ear fluid, endolymph. This in turn affects electrical activity of hair cells and so auditory nerve **(24)**. Zhang found that hypertensive patients with retinal arteriosclerosis had hearing threshold above patients with hypertension without arteriosclerosis which may indicate the role of arteriosclerosis associated with hypertension in hearing Loss **(38).** Inhibitory effects of endothelium against vasoconstrictor stimuli e.g. nor-epinephrine decrease with aging and hypertension **(61- 63)**.

High pressure in vascular system may cause inner ear hemorrhage which may cause progressive hearing loss **(1).**

Acetyl choline, an important neurotransmitter having direct effect on efferent nerve terminal and the bottom of hair cells, adjusts the hearing function. Long-term hypertension affects the secretion of Acetyl choline, result in abnormal accommodation of hearing and final damaging of hearing **(2)**. During hypertension, sodium is retained and extra cellular volume is enlarged then in inner ear, the volume of perilymph increases in particular and this lead to impaired conduction through the inner ear fluid with affection of high and low frequency disorders of conduction function of fenestrae. Hypertension is for the organ of hearing an important risk factor in predisposed subjects with affection of inner ear is equally malignant and has a similar background as glaucoma **(64)**. Increase in hydrostatic pressure could itself affect inner ear microcirculation function An imbalance of autonomic nervous system in hypertension could also affect inner ear function, autonomic nervous system innervate inner ear. These are good studies of adrenergic and cholinergic activity in inner ear **(32)**. Oxidative stress has been implicated as an important mechanism of vascular endothelial dysfunction induced by aging **(65,66)**. It was also been recently demonstrated to be an important path-physiological mechanism of alternation of microcirculation which is hypertension associated **(67)**. Hypertension is associated with increase level of reactive oxygen species which may scavenge endothelium derived NO and therapy diminish it vasorelaxant effects **(68).** Recent observations link oxidative stress to further damage in inner ear caused by endothelial dysfunction in cochlear microcirculation **(69)**.

Conclusion

In conclusion, high blood pressure is a risk factor for hearing loss not only associated with increase in hearing threshold (worse hearing) in hypertensive persons, but also associated with increase percentage of affection with hearing loss. In hypertensive patients, hearing loss is at high frequencies, 8000 Hz-frequency is the most affected frequency. Plasma fibrinogen level and ANP level are elevated with high blood pressure; direct relationship is present between them and hearing deterioration. That may indicate that hearing deterioration which associated with high blood pressure may be due to high plasma fibrinogen level and high plasma atrial natriuretic peptide level not due to high blood pressure.

Recommendation

- Early diagnosis of arterial hypertension, must take part in hearing loss-control programs.
- 8000 Hz-frequency can be used in early detection of hearing affection in hypertensive patients.
- Drugs that can decrease level of plasma fibrinogen can help in preservation of hearing in hypertensive patients.
- Plasma ANP level and its control can help not only in control of hypertension but also in hearing loss control

Corresponding author
Nawal B. Ali
[1]Physiology, Faculty of Medicine, El Azehar University

References

(1) LuCiana LM, Eduardo AR, Tiemi M. Hypertension as of factor associated with hearing loss. Brazilian Journal of OTo- rhynolaryngology, 2006;72(4), 533-40.

(2) Li Sui, Gong S, Yang Y, and Yu Qingsong. Effect of hypertension on hearing function, Lactic Dehydrogenase and Choline estrases of Cochlea in older rats. Journal of Huazhong University of Science and Technology, 2003; 23(3), 306-9.

(3) Esparza CM, Jauregui- Renand K, Morelos CM, Muhl GE, Mendez MN , Carillo NS, Bello NS and Cardenas M. Systemic high blood pressure and inner ear dysfunction. Clinical Otolaryngology, 2007; 32(3): 173-8.

(4) Elizabeth PH, Steven RW, Nathalalie R, and Eleanor MS. Race and sex differences in age related hearing loss. American Geriatrics Society, 2005; 53: 2119-27.

(5) Mosnier I., Teixerira M., and Loiseau A. Effects of acute and chronic hypertension on the labyrinthine barriers in rat. Hearing Research, 2001; 151: 227-236.

(6) Ulf R, and ValterS. Age related hearing loss and blood pressure. Noise Health, 2006; 8: 88-94.

(7) Nazar J. Otarola F. and Acevedo I. Audicion del paciente hipertenso cronico co controlado. Rev Otorrinolaringol CirCuello, 1992; 52(2): 97-104.

(8) Hansen CC. Perceptive hearing loss and arterial hypertension. Arch Otolaryngol, 1968; 87(2): 119-22.

(9) Mc Cormick JG, Harris DT, Hartley CB, and Lassiter RB. Spontaneous genetic hypertension in the rat and its relationship to reduced ac cochlear potentials. Proc. Natl Acad. Sci. USA, 1982; 79: 2668-72.

(10) Guyton AC and Hall JE.textbook of Medical Physiology 11 th ed.Philadelphia, Pa: WB Saunders Companey; 2006.

(11) Sheila RP, Lenisk, Evelyn OT, Kathleen MP, Alhaji Mb,and Xiaohui X.Prevalence of hearing loss in black and white elders. Journal of Speech Language and Hearing Research 2009; 52: 973-989.

(12) American National Standards Institute. Methods for manual pure-tone threshold audiometry. ANSI s3, 1978; 21.

(13) Elizabeth PH, Ami SP, Sheila P, kim ST, Jane AC, Evelyn T, Emily K, Tamara BH, Suzanne S, Jing Zahong D, and Anne BN. Hearing sensitivity in old adults. J Am Geriatric Soc, 2011; 59 (6): 972-9.

(14) Isabelle M, Marie T, Aiain L, Isabelle F, Oliver S, Clande A, and Evetyne F. Effects of acute and chronic hypertension on the labyrinthine barriers in rat. Hearing Research, 2001; 151(1-2): 227-36.

(15) Esparza CM, Jauregui- Renaud K, Morelos CM, Muhi GE, Mendez MN, Carillo NS, Bello NSR, and Cardenas M.Systemic high blood pressure and inner ear dysfunction Clin. Otolaryngol, 2007; 32: 173-8.

(16) Safar ME, and Frohlich ED. The arterial system in hypertension. Hypertension, 1995; 26: 10.

(17) Makishima, K. Arteriolar sclerosis as a cause of presbycusis. Otolargnology, 1978; 86(2), 322-326.

(18) Fang YY. Image analysis of arterial vessels of the internal auditory meatus during presenile and aged with hypertension and atherosclerosis. Zhonghua Er Bi Yan Houke Za Zhi, 1993; 28(2) : 91-3.

(19) Kathleen MH, and Helane A. Association between cardiovascular health and hearing function. American Journal Audiology, 2010; 19: 26-35,

(20) Karamitsos DG, Kounis NG, Zavras GM, Kitrou MP, Goudevenos JA, papdaki PJ and KoutsoJ annis CM. Brainstem auditory evoked potentials in patients with ischemic heart disease. Laryngoscope, 1996; 106: 54-7.

(21) Parving A, Hein Ho, Suadicani P, OstriB and Gyntelberg F. Epidemology of hearing disorders. Some factors affecting hearing. The Copenhagen Male Study. Scandinavian Audiology, 1993; 22: 101-7.

(22) Raymond HH, and Stacy RK. The influence of cardiovascular health on peripheral and central auditory function in adults. American Journal of Audiology, 2010; 19: 9-16.

(23) Brant LJ, Gordon, Salant S, Pearson JD, Khein LL, Morrell CH, and Metter EJ. Risk factors related to age-associated hearing loss in the speech frequencies. Journal of the American Academy of Audiology, 1996; 7: 152-160.

(24) Elizabeth PH, Ami SP, Sheila P, Kim ST, Jane AC, Evelyn T, Emily K, Tamara BH, Suzanne S, Jing Zhong D, and Anne BN Hearing sensitivity in older adults: Associations with cardio vascular risk factors in the health, Aging, and Body composition Study. J Am Geriatric Soc, 2011; 59 (6) : 972-9

(25) Carrasco VN, Prazma J, and Faber JE. Cochlear microcirculation effect of adrenergic agonists on arterioler diameter.Archi Otolaryngol Head Neck Surg, 1990; 116: 411-7.

(26) Gates GA, Cobb JL, Dagostino RB, and Wolf PA the relation of hearing in the elderly to the presence of cardiovascular disease and cardiovascular risk factors. Arch Otolargnol Head Neck Surg, 1993; 119:156-61.

(27) Zhang J, Zhou H, and Zhang G, Xu Y. A study on early hearing impairment with essential

hypertension. Lin Chung Er Bi Yan Hon Ton jing Wai Ke Za Zhi, 2009; 23 (16) :731-3.

(28) Minka H, Moshe R, Alfred L Nuttal, and Merie L. Influence of blood viscosity on cochlear action potentials and oxygenation. Hearing Research, 1982; 187-198.

(29) Heigl F, Hettich R, suckfuell M, Luebbers CW, Osterkorn D, Osterkorn K, and Canis M. Fibrinogen /LDL aphresis as successful second line of sudden hearing loss. Atheroscler Suppl, 2009, 10(5) : 95-101.

(30) Lu L Hong Z, Ju J, Du X, Gu P, Wu J, Wang X, Zhou S, and Gu X. The relationship between fibrinogen level and pathogenesis of sudden sensorineural hearing loss. Lin Chung Er Bi Yan Hou Tou Jing Wai Ke Za Zhi, 2008; 22 (1) : 8-13.

(31) Nadar S, and Lip Gy. The prothrombotic state in hypertension and the effects of antihypertensive treatment. Curr Pharm Des, 2003; 9(21) : 1715-32.

(32) McCormick JG, Harris CB, Hartley CB, and Lassiter R.B. Spontaneous genetic hypertension in the rat and its relationship to reduced ac cochlear potentials. Medical Science, 1982; 79: 2668-72.

(33) Oiao L, Han Y, Zhang P, Cao Z, and Oiu J. Detection of atrial natriuretic peptide and its receptor in marginal cells and cochleafrom developing rats. Neuroendocrinology letters, 2011; 32(2), 187-192

(34) Borghi C, Modugno GC, Brandolini C, and Pirrodda A. Is there a role for atrial peptides in the labyrinthine disease. Medical Hypotheses, 2006; 66(6) : 1188-90

(35) Nagahar K, Fisch U, and Yagi N. Perilymph oxygenation in sudden and progressive sensorineural hearing loss. Acta Otoloryngol, 1983,;l 96: 57-68

(36) Rarey KE, Ma YL, and Gerhardt KJ. Correlative evidence of hypertension and altered cochlear microhomeostasis: electro-physiological changes in the spontaneously hypertension rat. Hear research, 1996; 102: 63

(37) Borg E, and Viberg A. Age-related hair cell loss in spontaneously hypertensive and normotensive rats. Hear Research, 1987; 30:111.

(38) Shi X. Physiopathology of the cochlear microcirculation.Hearing Research, 2011; 282(1-2) : 10-24.

(39) Nuttal AL. Sound induced cochlear ischaemia hypoxia as a mechanism of hearing loss. Noise Health, 1999; 2: 17-31.

(40) Peter T, Koren J, Cruickshanks, Baren EK, Ronald K, and David MN. The associateion between cardiovascular disease and cochlear function in older adults .Journal of Speech, Longuage, and Hearing research, 2005; 48: 473-81.

(41) Schuknecht HF & Gacek MR. cochlear pathology in presbycusis. Ann. Otol. Rhinol. Laryngol, 1993; 102: 1-16

(42) Nakashima T, Naganawa S, Sone M, Tominaga M, Hayashi H, and Yamamoto H. Disorders of cochlear blood flow. Brain Research Reviews, 2003; 43: 17-28.

(43) McCormick JG, Hartly CB, Harris CT and Ens GE.J. Abstract. Acoustic. Soc. Am. 1978; 64:S133

(44) Reimann K, Krish namoorthy G, Wier WG, and Wangemann P. Gender differences in myogenic regulation along the vascular tree of the gerbil cochlea. Plos One, 2011; 6(9) : 25659.

(45) Carlisle L, Aberdeen J, Forge A, and Burnstock G. Neural basis for regulation of cochlear blood flow: peptidergic and adrenergic innervation of the spiral modiolar artery of the guinea pig. Hear. Research, 1990; 43:107-113.

(46) Rauchegger H , and Spoendlin H. Damage of the basilar memberane by acoustic stimulation. Arch, Otolaryngol, 1981; 232: 117-22.

(47) Maass B. Blood supply of internal ear. Anatomic functional consider ations HNO, 1982; 30(10) : 355-64.

(48) Gruber DD, Dang H, Shimozono M, Scofield MA , and Wangemann P. Alpha 1A- adrenergic receptors mediate vasoconstriction of the isolated spiral modiolar artery *in vitro*. Hear Research, 1998; 119, 113-24.

(49)Laurikainen EA, Costa O Miller JM, Nuttal AL, Ren Ty, Masta R, Quirk WS, and Robinson PJ. Neuronal regulation of cochlear blood flow in the guinea pig. Journal Physiol, 1994; 480 (3) : 563-73.

(50)Mclaren GM, Quirk WS, Laurikainen E, Coleman JK, Seid man MD, Dengerink HA, Nuttall AL, Miller JM, and Wright JW. Substance P increases cochlear blood flow without changing cochlear electrophysiology in rats. Hear. Research, 1993; 71: 183-9.

(51)Ren TY, Lauri Kainen E, Quirk WS, Miller JM, and Nuttal AL. Effects of electrical stimulation of the superior cervical ganglion on cochlear blood follow in guinea pig. Acta Otolaryngol, 1993; 113: 146-51.

(52) Scherer EQ, Arnold W, and Wangemann P. Pharmacological reversal of endothelin-1 mediated constriction of the spiral modiolar artery: a potential new treatment for sudden sensorineural hearing loss. BMC Ear Nose Throat Disorders, 2005; 5: 10.

(53) Xiaourui Shi. Pathophysiology of cochlear microcirculation. Hearing Research 2011; 282: 10-24.

(54) Wangemann P, and Liu J. Osmotic water permeability of capillaries from the isolated spiral ligament. Hear. Res, 1996; 95: 49-56.

(55) Dai M, Nattall A, Yang Y, and Shi X. Visualization and contractile activity of cochlear pericytes in the capillaries of the spiral ligament. Hearing research, 2009; 254: 100-7.

(56) Degoute C.S, Preckel MP, Dubreuil C, Banssilon V and Duclaux R. sympathetic nerve regulation of cochlear blood flow increase in blood pressure in humans. Eur journal Appl. Physiol. Occup. Physiol, 1997; 75: 326-32.

(57) Seidman MD, Quirk WS, and Shirwany NA. Mechanisms of alterations in the microcirculation of the cochlea. Ann NY Acad Sci, 1999; 884: 226-32.

(58) Prazma J, Carrasco VN, Butler B, Waters G, Anderson T , and Pillsbury. Cochlear microcirculation in Young and old gerbils. Arch. Otolaryngol. Head Neck surg, 1990, 116: 932-6 .

(59) Brown JN, Miller J M , and Nuttall AL. Age-related changes in cochlear vascular conductance in mice. Hear Research, 1995; 86: 189-94.

(60) Gates GA, Cobb JL, D'Agostino R.B and, Wolf PA. The relation of hearing in elderly to the presence of cardiovascular disease and cardiovascular risk factors. Arch Otoloryngal Head Neck Surg, 1993; 119:156-61.

(61) Dohi Y, Thiel MA, Bühler FR, and Lüscher TF. Activation of endothelial L. arginine pathway in resistance arteries. Effect of age and hypertension. Hypertension, 1990; 16(2) : 170-9.

(62) Lüscher TF, Dohi Y, and Tschudi M. Endothelium-dependent regulation of resistance arteries: alternations with aging and hypertension. J. Cardiovasc pharmacol, 1992; 19(5) : 34-42.

(63) MAtz RL, Schott C, Stoclet JC, Andrian tsitoha Age-Related endohrelial dysfunction with respect to Nitric Oxide, endothelium- Drived Hyperpolarizing Factor and cyclooxygenase products. Physiol Reserch, 2000; 49: 11-18.

(64) Markova M. the Cochlea vestibular syndrome in hypertension. Cesk, Otolaryngol, 1990, 39: 89-97.

(65) Katherine A, Blackwell, Joseph P, Sorenson, Darcy M, Richardson, Leslie A, Smith, Suda O, and Nath K Mechainsms of aging induced impairment of endothelium-dependent relaxation. American Journal of physiology-Heart and Circulatory Physiology, 2004; 287: 2448-2453.

(66)Ohnaka K, and Takayanagi R. Change of endothelial function with aging. Nihon Rinsho, 2005; 63(6) : 989-993.

(67)|Vicaut E: Hypertension and the microcirculation. Arch Mal Coeur Vaiss, 2003, 96(9) : 893-903.

(68)Wind S, Beuer tein K, Melanie E, Armitage Taye A, Arun H, Kumar, Janowitz D, Neffc, Ajay M, Shah, Wingler K, and Harald H. Oxidative stress and endothelial dysfunction in Aortas of ages spontaneously hypertensive rats by Nox is reversed by NADPH oxidase inhibition. Hypertesnion, 2010; 56: 490-7.

(69) Ciorba A, Chicca M, Bianchini C, Aimonic, and Pastore A. Sensorineural hearing loss and endothelial dysfunction due to oxidative stress. Journal of Internation advanced Otology, 2012; 8(1) :16-20.

11/10/2012