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The difference of otic capsule density, auditory ossicles density, and hearing threshold in osteoporosis and non-osteoporosis patients at Saiful Anwar Public Hospital 2017

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ABSTRACT

Background: Osteoporosis is a systemic disease and involves all bones, including temporal bone. Demineralization of temporal bone including otic capsule and auditory ossicles is suspected to be the cause of hearing loss.

Purpose: This study aims to determine whether osteoporosis can cause the decrease of otic capsule and auditory ossicles density and increase the hearing threshold.

Method: an Observational analytic study with a cross sectional design involving 18 osteoporosis patients and 18 non-osteoporosis patients who had bone mineral density examination. The hearing was examined with Interaccoustic AA222 audiometer while otic capsule and auditory ossicles density were measured using Toshiba Aquilion 128 CT.

Results: Hearing loss was found in 22 of 36 osteoporosis patients ears (61.11%) and 8 of 36 non-osteoporosis patients ears (22.22%). The density of malleus, incus, ROI I, and ROI II between the osteoporosis and non osteoporosis groups showed significant differences ($p<0.05$; malleus: 1147 ± 85 HU vs 1212 ± 80 HU; incus: 1127 ± 94 HU vs 1184 ± 81 HU; ROI I: 1895 ± 72 HU vs 1981 ± 101 HU; ROI II: 1903 ± 61 HU vs 1968 ± 88 HU).). While for stapes density (1086 ± 90 HU vs 1110 ± 86 HU) did not show a significant difference ($p>0.05$). The hearing threshold between two groups (30.83 ± 9.42 dB vs 23.26 ± 8.09 dB) showed significant differences ($p<0.05$). The density of malleus, incus, stapes, ROI I, and ROI II negatively significant ($p<0.05$) correlated to the hearing threshold with each correlation coefficient were -0.498, -0.391, -0.255, -0.690, and -0.562.

Conclusion: The density of malleus, incus, and otic capsule between the osteoporosis and non-osteoporosis groups showed significant differences. The density of the otic capsule and auditory ossicles are negatively correlated with the hearing threshold.

Keywords: osteoporosis, hearing loss, bone mineral density, auditory ossicles density, otic capsule density, bone metabolism, temporal bone.
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INTRODUCTION

Hearing loss is associated with decreasing quality of life. There are many factors that can affect the rate of deterioration of hearing loss, such as age, genetics, ototoxic drugs, infection, environment, occupational, and noise exposure. In various studies, it is mentioned that osteoporosis is also one of the risk factors for hearing loss. In 2016, meta-analysis study by Upala, et al. states that osteoporosis can be a risk factor for hearing loss and may play an important role in age-related hearing loss.[1]

Osteoporosis is a progressive systemic bone disease characterized by a low density of bone mass and deterioration of bone microarchitecture, so the bones become fragile and break easily.[2] The decrease of bone mass due to aging begins in decades 4-5 life at a rate of 0.3-0.5% per year.[3] The rate of incidence of osteoporosis from the global population is 5%.[4]

Most osteoporosis affects the bones of the hips and vertebrae, however, the temporal bone can also be damaged. Demineralization of the temporal bone including the otic capsule and auditory ossicles appear to be one factor that can cause hearing loss. Demineralization of the otic capsule may cause sensorineural hearing loss.[1,5] Research by Babich, et al. found the conductive hearing loss in osteoporosis. Babich et al. suggest that osteoporosis can also affect malleus, incus, and stapes so that cause conductive hearing loss.[5]

Research on hearing loss due to osteoporosis began to study widely, but in Indonesia has never been reported. Also, the mechanism of hearing loss due to osteoporosis also cannot be explained certainty. Some researchers suggest that demineralization of the hearing bone and otic capsule as the cause of hearing loss.[1,6]

METHODS

This research was an observational study with a cross sectional design approach to investigate the

relationship between osteoporosis and the risk of hearing loss. The study was conducted after ethical clearance was obtained. Sampling in this study using consecutive techniques sampling. The inclusion criteria of case group were osteoporosis patient aged 19-64 years who came to osteoporosis clinic of Saiful Anwar Public Hospital diagnosed with bone mineral density (BMD) and have not received bisphosphonate therapy. The inclusion criteria of the control group are subjects aged 19-64 years who came to osteoporosis clinic Saiful Anwar Public Hospital and undiagnosed of osteoporosis from BMD examination. Patients excluded if there were anatomical abnormalities of the ear, congenital or birth deafness and outer and middle ear diseases which may result in the permanent hearing loss by looking the outcomes of otoscopy examination, history of acoustic trauma, head trauma, post ear surgery, working in noisy places, and hypertension.

Subjects who are willing to follow the study are examined using pure tone audiometry test using Interaccoustic AA222 audiometer with decibel unit (dB) and High-Resolution CT Scan of Mastoid bone using High-Resolution CT scan Toshiba Aquilon 128 slice to assess the density of otic capsule and auditory ossicles with Hounsfield Unit (HU).

The hearing threshold was defined as the mean of lowest pure tone intensity can be identified by subjects in 500, 1000, 2000 and 4000 Hz. Hearing loss was defined as a hearing threshold over 25 dB. The density of otic capsule is the result of the area density measurement on the pars petrosus of the temporal bone in the 1 mm area anterior to the foramen ovale (Region of Interest / ROI I) and 1 mm anterior to the internal auditory canal (ROI II). Auditory ossicle density is the result of bone area density measurement from malleus, incus, and stapes.

Variables normality were checked by Kolmogorov Smirnov test. Comparison of otic capsule density, auditory ossicles density, and hearing threshold in the case group with the control group tested with Mann Whitney test. The correlation of otic capsule density, auditory ossicles density, and hearing threshold was tested by Spearman test.

Table 1 Comparison of the Density of Otic Capsule and Auditory Ossicles between Osteoporosis and Non-osteoporosis Group

	Osteoporosis	Non-Osteoporosis	
Density	**Mean ± SD**	**Mean ± SD**	**p**
Malleus (HU)	1147 ± 85	1212 ± 80	0.000
Incus (HU)	1127 ± 94	1184 ± 81	0.000
Stapes (HU)	1086 ± 90	1110 ± 86	0.195
ROI I (HU)	1895 ± 72	1981 ± 101	0.000
ROI II (HU)	1903 ± 61	1968 ± 88	0.000

Table 2 Types and Degrees of Hearing Loss

Types and Degrees of Hearing Loss	Osteoporosis		Non-Osteoporosis	
	n	**%**	**n**	**%**
• Mild conductive	2	5.56	0	0
• Mild sensorineural	16	44.44	5	13.89
• Moderate sensorineural	2	5.56	2	5.56
• Mild mixed	0	0	1	2.78
• Moderate mixed	1	2.78	0	0
• Moderate severe mixed	1	2.78	0	0

RESULTS

The study was conducted from May to October 2017 by the amount of sample was 36 people consisting of 3 males and 33 females. Subject consisted of 2 groups, 18 patients with osteoporosis and 18 non-osteoporosis patients. Non-osteoporosis patients comprised of 12 patients osteopenia and 6 people with normal BMD examination results. Mean of age in osteoporosis group and non-osteoporosis group was 47 ± 14, 84 years and 44.28 ± 13.23 years.

The density mean of malleus, incus, stapes, ROI I, and ROI II of the osteoporosis group is lower than non-osteoporosis group (both osteopenia and normal) (Table 1, Figures 1, and Figure 2). The number of research subjects as many as 36 people consists of 72 ears. Of the osteoporosis and non-osteoporosis group, 66.67% and 33.33% subjects of the study experienced a hearing loss. A total of 22 ears (61.11%) of the osteoporosis group experienced a hearing loss. While in the non-osteoporosis group, 8 ears (22.22%) had hearing loss, where all of them had osteopenia. The mean of hearing threshold and each frequency from osteoporosis group were higher than the non-osteoporosis group, both osteopenia and normal (Table 2 and Figure 3).

From the results of Mann Whitney test, there was the significant difference of the mean density of ROI I, ROI II, malleus, and incus, the mean of hearing threshold and each frequency between osteoporosis and non-osteoporosis group ($p < 0.05$). Only the stapes density was not significantly different ($p > 0.05$).

Based on the Spearman test, osteoporosis and non-osteoporosis group were negatively significant correlated to the mean of all hearing threshold ($p < 0.05$) (Table 4). Similarly, the density of ROI I, ROI II malleus, incus, and stapes were negatively significant correlated to the hearing threshold ($p < 0.05$) (Table 5).

Table 3 Comparison of Hearing Threshold Between Osteoporosis and Non-osteoporosis Group

	Osteoporosis	Non Osteoporosis	
	Mean ± SD	Mean ± SD	p
Hearing Threshold (dB)	30.83 ± 9.42	23.26 ± 8.09	0.000
250 Hz (dB)	28.33 ± 10.89	19.72 ± 5.47	0.000
500 Hz (dB)	30.00 ± 11.15	23.19 ± 6.23	0.000
1000 Hz (dB)	30.14 ± 10.52	21.94 ± 8.80	0.000
2000 Hz (dB)	32.22 ± 11.86	24.58 ± 9.13	0.003
4000 Hz (dB)	30.83 ± 11.92	23.06 ± 15.22	0.018
8000 Hz (dB)	37.78 ± 19.91	19.17 ± 18.57	0.000

Table 4 Correlation of Osteoporosis and Non-osteoporosis Group with Hearing Threshold

Mean	r	p
Hearing Threshold	-0.472	0.000
250 Hz	-0.451	0.000
500 Hz	-0.312	0.000
1000 Hz	-0.449	0.000
2000 Hz	-0.376	0.000
4000 Hz	-0.357	0.000
8000 Hz	-0.496	0.000

Table 5 Correlation of Otic Capsule and Auditory Ossicles Density with Hearing Threshold

	Hearing Threshold	
Density	r	p
Malleus	-0.498	0.000
Incus	-0.391	0.001
Stapes	-0.255	0.030
ROI I	-0.690	0.000
ROI II	-0.562	0.000

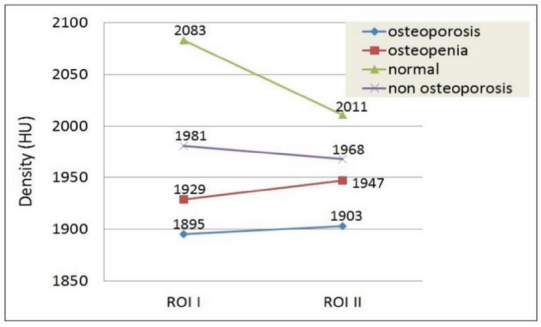

Figure 1 Mean of Otic Capsule Density

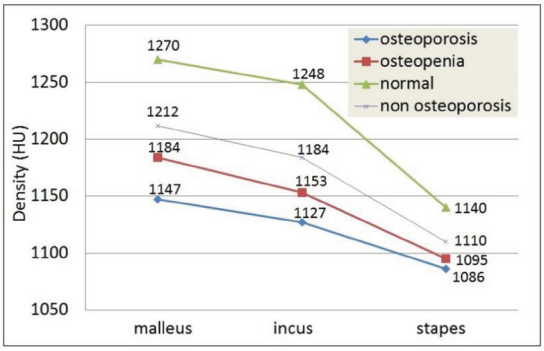

Figure 2 Mean of Auditory Ossicles Density

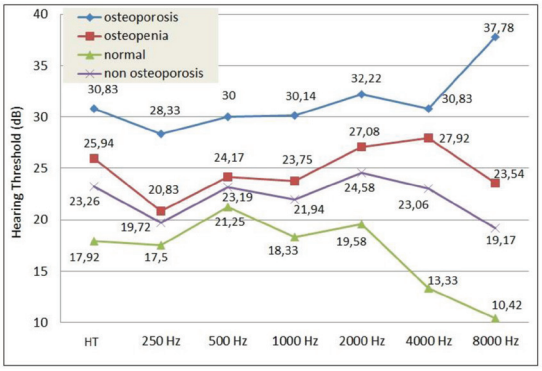

Figure 3 Mean of Hearing Threshold

DISCUSSION

The prevalence of hearing loss based on ear numbers in this study was 61.11% in the osteoporosis group and 22.22% in the non-osteoporosis group. Comparison of hearing loss prevalence between osteoporosis and non-osteoporosis group by type were sensorineural 50%: 19.45%, conductive 5.56%: 0% and mixed 5.56%: 2.76%. The results of this study is similar to study by Kim et al. and Kahveci et al., in which most types of deafness were sensorineural hearing loss with 56.5% and 36%, respectively.[6,7] Research Yeh et al. states the incidence of sudden sensorineural hearing loss in osteoporosis patients 1.76 times higher than non-osteoporosis.[8]

Mean of hearing threshold, and each frequency from osteoporosis group was higher than the non-osteoporosis group. Mean of the hearing threshold for osteoporosis, osteopenia, and normal group was 30.83 ± 9.42 dB, 25.94 ± 8.46 dB, and 17.92 ± 3.38 dB. The study by Bhavya, et al. and Kim, et al. also states that the hearing threshold of all frequencies from the normal group is better than the osteopenia and osteoporosis group.[5,6] These results were similar with Kahveci et al. where the highest mean of the hearing threshold is obtained in groups of osteoporosis, osteopenia, and normal, respectively. However, Kahveci et al. obtained a lower mean than in this study that is 24.03 ± 18.22 dB, 19.89 ± 16.67 dB, and 13.26 ± 7.39 dB.[7]

From the results of the differential analysis, we found the significant difference between the mean

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of hearing thresholds and each frequency between the osteoporosis and non-osteoporosis group ($p < 0.05$). Kahveci et al. stated there was a significant difference in the mean of hearing threshold at 500-8000 Hz frequency between the osteoporosis and control group and the mean of hearing thresholds at 500-2000 Hz frequency between the control and osteopenia group. In the osteopenia and control group, there was no significant difference in all frequencies.[7]

In this study, it was found a negative correlation between osteoporosis and non-osteoporosis groups with mean of threshold and each frequency. The coefficient of correlation between osteoporosis and non-osteoporosis with the mean of the hearing threshold is -0.472 which means lower bone mass density, higher hearing threshold.

The mean density of malleus, incus, stapes, ROI I, and ROI II of the osteoporosis group was lower than in the non-osteoporosis group, both osteopenia and normal. In this study, the mean density of malleus in the osteoporosis, osteopenia, and normal groups were 1147 ± 85 HU, 1184 ± 70 HU, and 1270 ± 69 HU. The mean density of incus in the osteoporosis, osteopenia, and normal groups were 1127 ± 94 HU, 1153 ± 66 HU, and 1248 ± 73 HU. While the mean density of incus in osteoporosis, osteopenia, and normal group was 1086 ± 90 HU, 1095 ± 88 HU, and 1140 ± 75 HU.

Otic capsule bone consists of lamellar bone with a few of Haversian canal and blood vessels as well as a compact bone tissue. The normal otic capsule has a density of about 2000 HU.[9] In this study, the mean density of ROI I in the osteoporosis, osteopenia, and normal groups were 1895 ± 72 HU, 1929 ± 55 HU, and 2083 ± 94 HU. The mean density of ROI II in the osteoporosis, osteopenia, and normal group was 1903 ± 61 HU, 1947 ± 66 HU, and 2011 ± 112 HU. The results of the study from Handoko, et al. in patients with chronic kidney disease and normal hearing obtained a density of otic capsule at 1 mm area anterior foramen ovale (ROI I) of 2095 ± 315 HU and 1 mm in the anterior internal acoustic canal (ROI II) of 2051 ± 293 HU. Whereas in chronic kidney disease patients with sensorineural hearing loss obtained lower density, each of 1867 ± 285 HU and 1864 ± 190 HU.[10] In another study by Erkoc about bone remodeling on the pars petrosus temporal bone of patients with chronic kidney disease was obtained density of pars petrosus temporal bone in control population on ROI I of 1909 ± 54 HU and ROI II of 1249 ± 53 HU.[11] From the results of differential analysis test, we found significant differences in density of ROI I, ROI II, malleus, and incus between osteoporosis and non-osteoporosis ($p < 0.05$). Only the stapes density was not significantly different ($p > 0.05$).

The density of malleus, incus, stapes, ROI I, and ROI II were negatively significant correlated ($p < 0.05$) to the mean of hearing threshold. The correlation coefficient between the density of malleus, incus, stapes, ROI I, and ROI II with mean of hearing threshold was -0.498, -0.391, -0.255, -0.690, and -0.562. This suggests that the lower the density of the otic capsule and auditory ossicles, the higher mean of hearing threshold. In the study from Handoko, et al in patients with chronic kidney disease also obtained similar results to the correlation of otic capsule density on ROI I and ROI II against hearing threshold with the correlation coefficient -0.427 and -0.402 respectively.[10]

These results show the role of bone metabolism, especially temporal bone on hearing the loss in osteoporosis. On normal conditions, there only a little or no remodeling process occurs in otic capsule.[9] The otic capsule is the densest bone in the human body. Post ossification process at the 16th week of pregnancy, modeling and remodeling process of the otic capsule is almost absent.[12] Temporal bone turnover is only 0.1% per year compared to 10% per year of turnover on peripheral bone.[13]

Bone remodeling is managed by the balance of cytokines and their receptors i.e osteoprotegerin (OPG), Nuclear Factor Receptor Activator kB (RANK), and RANK Ligand (RANKL). The Ligand RANK is located on the surface of the osteoblasts and bind to the RANK receptor on the surface of the osteoclast precursor cell, which is resulting in osteoclast differentiation and activation and bone remodeling. Osteoprotegerin competes with RANKL to bind to the RANK receptors so that the bone remodeling is decreased.[14]

Osteoporosis results from imbalances of bone resorption and formation which can be physiological or pathological. Osteoporosis in aging more due to decreased osteoblast supply. While osteoporosis in estrogen deficiency tends to be associated with increased activity of osteoclast.[3] Estrogen controls osteoclast differentiation by inhibit the interaction between RANK and RANKL, production of IL-6, IL-1 and or TNF-α, IL-11, IL-7 and TGF-ß.[3] Hughes, et al, quoted by Oursler, demonstrated that estrogen can induce apoptosis and osteoclast death so it can directly decrease resorption activity.[15] Estrogen deficiency will also decrease OPG production by osteoblasts.[3]

The demineralization process of otic capsule is associated with an increase of hearing thresholds on metabolic bone disease such as Paget's disease and osteogenesis imperfecta.[5] Monsell, et al. states that there is a strong and significant relationship between the density of the otic capsule and hearing threshold in patients with Paget's disease, in which

lesions on the increase of the hearing threshold is assessed to be located in the cochlea due to normal result of auditory brainstem response (ABR) test results. Monsell suspects that the bone that had demineralized will absorb acoustic energy, reducing the amplitude of the basilary membrane shift, and disrupt the process of mechanical signals transduction to electrical signals. Furthermore, the endocochlear potential may also be reduced to Paget's bone.[16] Demineralization process of otic capsule is also suspected to occur in people with osteoporosis.

Cochlear bone is designed to detect acoustic energy. The difference of impedance between the cochlear liquid and the otic capsule is very important. Acoustic energy will come out of the cochlea if there is no large difference between the fluid impedance of cochlea and otic capsule. To prevent loss of acoustic energy from cochlear, it required the highest impedance from the cochlear otic capsule. This process requires a solid bone to keep the acoustic energy out of the cochlea to the surrounding structure. Changes in the density of otic capsule may disrupt this process.[17-19]

The results of this study show the high prevalence of hearing loss in osteoporosis patient so it can be considered to perform BMD examination in hearing loss patients with suspected have osteoporosis. Otherwise, in osteoporosis, osteopenia, or patients with risk factors for osteoporosis should be more careful about the likelihood of hearing loss. Therefore we can do early detection and prevention of decreased quality of life of patients due to worsening conditions of osteoporosis and/or hearing loss. Also, it is necessary to study the effectiveness of osteoporosis therapy in osteoporosis patients with hearing loss to treat or inhibit the process of hearing loss.

CONFLICT OF INTEREST

The author declares there is no conflict of interest regarding publication of this manuscript and have got patient's permission in this article.

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