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RESEARCH ARTICLE

Panoramic Radiography Measurements Not Correlated with BMD Results in End-stage Chronic Kidney Disease Patients

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Abstract

Chronic kidney disease (CKD) is a disorder of the kidney defined by a glomerular filtration rate of less than 60 ml/min/1.73 m2 for a minimum of three months, progressive and irreversible. One complication is chronic kidney disease-metabolic bone disorders (CKD-MBD), which can cause osteoporosis. This is diagnosed using bone mineral densitometry-dual energy absorptiometry (BMD-DXA) and panoramic radiographs, which can also detect thinning of the mandibular cortex in patients with CKD. This study aims to determine the correlation between osteoporosis images on panoramic photos with the results of lumbar and hip areal T-scores in chronic kidney disease (CKD). This research is an observational study with a prospective approach and cross-sectional design. The subjects of this study were 52 patients with chronic kidney disease (CKD). Undergoing hemodyalize procedure (HD) at Dr. Soetomo General Hospital for February–March 2024. Data was collected by taking the results of the panoramic photo examination and BMD-DXA to see the results of the T-score in each patient—data analysis using the Spearman test on SPSS software. Which resulted in the p-values for the panoramic mandibular index (PMI), mandibular cortical width (MCW), and mandibular cortical index (MCI) with a lumbar T-score range of 0.093 to 0.676 and the PMI, MCW, and MCI with left-right hip T-score, the p-values ranged from 0.318 to 0.970 (all p-values >0.05). It can be concluded that there is no correlation between the results of the T-score for the lumbar and hip regions and the measurements of PMI, MCW, and MCI. Therefore, employing these three measurements as a standard for osteoporosis screening using panoramic x-rays is not feasible.

Keywords: BMD-DXA, CKD, osteoporosis, panoramic radiography, T-score

Introduction

Chronic kidney disease (CKD) is one of the problems in the field of nephrology with a high incidence rate, accompanied by a wide range of etiologies, and often begins without complaints or clinical symptoms unless it has entered the phase of kidney failure. The prevalence of chronic kidney disease in the United States reached 661,648 cases, increased to 3.5% in 2012, and increased 68% from 2000 to the end of December 2013. The prevalence of chronic kidney disease in Indonesia, based on physician-diagnosed interviews, increases with age, rising sharply at the age of 35–44 years (0.3%), followed by 45–54 years (0.4%), and peaking in the age group of 75 years and above (0.6%). Mineral and bone disorders are also common in chronic kidney disease patients. Most nephrologists concur that hyperphosphatemia, hypocalcemia, and vitamin D deficiency should be addressed concurrently. This can be achieved through the implementation of a low-phosphate diet, the use of phosphate binders, ensuring adequate intake of elemental calcium, and the administration of vitamin D supplements. The incidence of osteoporosis is also increased in CKD patients. A study showed that the prevalence of osteoporosis was 31.8% in CKD patients compared to 22% in controls. The study also concluded that body mass index (BMI) acts as a risk factor, whereas CKD patients with low BMI have a higher risk of osteoporosis.[1–3]

Bone mineral density (BMD), as determined by dual x-ray absorptiometry (DXA), has become the gold standard for diagnosing osteoporosis without fragility fractures. DXA is a straightforward, expeditious, painless, and secure examination that employs a low-dose x-ray

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technique. The low-dose dual x-rays (significantly lower than those used for x-rays and CT scans) can be safely repeated over time. DXA acquisition can provide images of the total body, the hip, the posterior-anterior lumbar spine (LS), and/or the forearm.[3,4]

Panoramic x-rays have become a commonly used imaging modality in dental practice. A patient may undergo a panoramic x-ray in addition to BMD-DXA because panoramic radiographs are useful for opportunistic osteoporosis risk screening, especially in dental settings, and can detect early changes in mandibular bone that correlate with systemic bone health. The accessibility and low dosage of these substances are of particular concern. In cases where osteoporosis is suspected, these tools can facilitate timely referral for DXA and subsequent management. Radiomorphometric measurements of panoramic x-rays have been successfully employed in the prediction of low bone mineral density in patients. Several mandibular cortical indices, including the mandibular cortical index (MCI), panoramic mandibular index (PMI), and mental index (MI), have been developed for this purpose.[5] Most studies have reported three key measurement indices on panoramic x-rays: mandibular cortical width (MCW), PMI, and Klemetti index (also known as the mandibular cortical index). Our findings indicate that MCI Class 3 (C3), MCW <3 mm and PMI ratio <0.3 are significantly associated with lower BMD T-scores and an increased risk of osteoporosis.[6] So, based on these studies, the principal objective of this study is to ascertain the correlation between panoramic examination and PMI measurements, MCW, and to evaluate MCI. Subsequently, the results will be correlated with those of the BMD-DXA examination of CKD patients who have undergone routine hemodialysis. It is anticipated that this analysis will yield novel insights into the use of panoramic x-rays as a screening method for the early detection of osteoporosis in patients with chronic kidney disease. This study aims to determine the correlation between osteoporosis images on panoramic photos with the results of lumbar and hip areal T-scores in end-stage chronic kidney disease (CKD).

Methods

This study employs an observational design with a prospective approach and a cross-sectional research design. The research subjects were recruited from patients with end-stage chronic kidney disease who underwent routine hemodialysis for more than five years at Dr. Soetomo General Academic Hospital in February and March 2024. The study employed the consecutive sampling technique, whereby every patient who met the inclusion criteria was sampled until a specified period had elapsed, thus ensuring that the requisite number of patients was included, with a total of 52 research subjects.

The patient was then examined using DXA to obtain a T-score value for each patient, followed by a panoramic x-ray examination to measure PMI and MCW and evaluate MCI. The researcher measured the T-score in the lumbar area, from L1 to L4, as well as in the right and left hip areas. T-score values are obtained using DXA tools, and bone density values are measured in this area (lumbar area and left-right hip) with those tools; the interpretation of the score is standard if T-score >−1, called osteopenia if the values of the score are>−2.5 or T-score ≤−1, and called osteoporosis if T-score ≤−2.5.

After that, we also measured PMI, MCW, and MCI on a panoramic x-ray examination. PMI was calculated as the ratio of the mandibular cortical thickness measured at the perpendicular line of the lower part of the mandible, at the center of the mental foramen, to the distance between the superior edge of the inferior mandibular cortex and the lower part of the mandible. MCW is a measurement of mandibular cortical thickness at the perpendicular line of the lower part of the mandible in the middle of the mental foramen (normal value >3.1 mm). MCI was calculated based on the appearance of the mandibular cortical border distal to the mental foramina. The data obtained were then analyzed and presented as research results. The cut-off used in this study was based on previous research, specifically for normal values of PMI >0.3 and MCW >3.1 mm, and for osteoporosis, MCI is classified as class 2–3. The statistical test used to analyze the data in this study was Spearman's correlation test, which was employed to examine the radio morphometric correlation in panoramic photographs with BMD results obtained using DXA in end-stage chronic kidney disease patients undergoing hemodialysis at Dr. Soetomo General Hospital. Spearman‘s test was chosen to test the

correlation between measurements in panoramic x-rays and T-scores because both data sets may not be normally distributed, may be ordinal, or the relationship between variables may be non-linear. Spearman's test provides valid and robust results under these conditions, making it a commonly used tool in radiology research.[5,6]

The study has been approved by the Health Research Ethics Committee of Dr. Soetomo General Academic Hospital, Surabaya, for ethical clearance with registration number 0528/KEPK/XI/2022. The relevant guidelines and regulations were followed during all procedures.

Results

The study's population consisted of 52 participants, comprising 33 female subjects and 19 male subjects. The mean age of the subjects was 46.62 (Table 1).

In the PMI and MCW examinations, using the Kolmogorov-Smirnov test to assess the data distribution, the following results were obtained: no normal data distribution was found, with p-values of 0.002 for the right PMI and 0.004 for the left PMI, and p-values of 0.000 for the right MCW and 0.001 for the left MCW. Therefore, the median and interquartile range (IQR) were calculated, yielding the following results: median right PMI was 0.25 with an IQR value of 0.085, the median left PMI was 0.2 with an IQR of 0.07, and the median for the right MCW was 3.35 with an IQR of 0.575, while the median for the left MCW was 3.4 with an IQR of 0.67. For MCI, the median was found at C2. In the T-score examination on BMD, a p-value of 0.200 was obtained, which means that the data distribution for the T-score value is usually distributed.

The BMD-DXA examination of the lumbar area and right-left hip revealed that low bone mass and osteoporosis were the most prevalent findings in both men and women. The data demonstrate a high prevalence of low bone mass and osteoporosis in all three areas examined (Table 2).

Subsequently, the measurements of PMI, MCI, and MCW on the right and left sides yielded osteoporosis results that were more pronounced in PMI, MCI, and the left-right MCW (Table 3). Thereafter, the correlation was quantified by the results of the BMD-DXA examination, specifically the T-score in the lumbar area and the left and right hips (Table 4). The results of the

Table 1 Age Distribution of CKD Patients

Age (Year)	Male n=19	Female n=33
20–29	3	1
30–39	2	4
40–49	7	7
50–59	6	17
60–69	1	4

Table 2 Characteristics of BMD-DXA Results Measured in the Lumbar and Right-Left Hip Areas

T-score Result	Male n=19	Female n=33	Total n=52
Lumbar region			
Normal	5	6	11
Low bone mass	8	15	23
Osteoporosis	6	12	18
Right hip region			
Normal	5	4	9
Low bone mass	7	16	23
Osteoporosis	7	13	20
Left hip region			
Normal	5	4	9
Low bone mass	7	14	21
Osteoporosis	7	15	22

Table 3 Measurement Characteristics of Panoramic X-rays

Variables	Category	n=52
PMI (right side)	Osteoporosis	44
	Normal	8
PMI (left side)	Osteoporosis	46
	Normal	6
MCI (right side)	C1	2
	C2	36
	C3	14
MCI (left side)	C1	2
	C2	36
	C3	14
MCW (right side)	Normal	14
	Osteoporosis	38
MCW (left side)	Normal	18
	Osteoporosis	34

Table 4 Results of the Correlation Test of PMI, MCW, and MCI Variables with T-score

Variables	n	Correlation Coefficient	p*
T-score in the lumbar area			
PMI (right side)	52	0.128	0.374
PMI (left side)	52	0.202	0.16
MCW (right side)	52	0.072	0.519
MCW (left side)	52	0.023	0.676
MCI (right side)	52	−0.240	0.093
MCI (left side)	52	−0.240	0.093
T-score in the hip area			
PMI (right side)	52	−0.018	0.902
PMI (left side)	52	0.079	0.586
MCW (right side)	52	0.016	0.911
MCW (left side)	52	−0.005	0.970
MCI (right side)	52	−0.144	0.318
MCI (left side)	52	−0.119	0.411

Note: *Spearman's test

analysis of the relationship between PMI, MCI, and MCW measurements and T-score results in the lumbar and right-left hip areas, using Spearman's correlation test, showed that there is no statistically significant relationship between the variables PMI, MCI, and MCW on the right ($p>0.05$).

Discussion

The majority of subjects have been diagnosed with abnormal conditions, including low bone mass and osteoporosis, in both male and female patients. The highest percentage is osteoporosis in women, which is in line with previous research that women are more susceptible to osteoporosis because of changes in hormone metabolism, especially a decrease in the hormone estrogen, during the menopausal phase or in conditions of CKD.[7] The process of bone formation is disrupted due to decreased estrogen. This phenomenon can be attributed to estrogen receptors in osteoclast progenitor cells and multi-nucleated osteoclasts, which enhance osteoclast sequestration activity while concurrently reducing osteoblast activity. CKD leads to hormonal and metabolic disturbances, damaging bone quality. The quality of bone depends upon the bone material's intrinsic properties. These properties include the capacity for replacement, the configuration of the microarchitecture, the extent of mineralization, the accumulation of micro-damage (microscale cracks), and the characteristics of the collagen (such as glycation and bone binding). Renal osteodystrophy is a bone quality and strength disorder caused by metabolic and hormonal disturbances associated with chronic kidney disease. It impairs bone turnover, mineralization, collagen, cortical and trabecular structure, and microarchitecture. This, in turn, increases the risk of fracture by reducing bone mass and quality.[7,8]

This study's results also indicate no statistically significant correlation between PMI and BMD outcomes. Consequently, PMI cannot be used as a reference for osteoporosis diagnosis based solely on BMD imaging. This finding is in line with the results of previous studies, which demonstrated no significant relationship between PMI and estrogen levels in patients with end-stage renal disease and osteoporosis. Reducing estrogen levels may enhance the sensitivity of osteoclasts to BMD.[9,10] However, the results of this study are in contradiction to those of a previous study, which identified a significant relationship between PMI and BMD in female CKD patients.[11] This phenomenon can occur in patients of premenopausal age, where a rapid decrease in BMD levels and a decrease in maxillary and lower mandibular cortex thickness are observed. The deterioration of renal function leads to secondary hyperparathyroidism, which has a discernible impact on both cortical and trabecular bone.[12] This study aimed to assess these differential effects through radiomorphometric indices

(MI, MCI, and PMI) and fractal dimension in patients with end-stage renal disease. The discrepancies between studies, including this one, may be attributed to the inherent limitations of PMI, which are primarily associated with inter-operator agreement and experience, as well as varying image quality, magnification, and distortion.[13]

No relationship observed between MCW and T-score values in the lumbar area or the right and left hip. This finding aligns with the results of a previous study, which also demonstrated a lack of significant correlation between MCW and clinical outcomes in patients with end-stage renal disease.[12] In contrast to a study, the Spearman correlation test found in the study that MCW in osteoporosis patients before anti-resorptive therapy was associated with BMD.[14] In addition, the results of previous studies are not the same; loss of lamina dura and changes in the MCW picture are related to plasma parathyroid hormone (PTH) levels, so that the lower the PTH level, it is possible that the MCW picture does not change or does not tend to lead to osteoporosis.[15] However, the results of this study are in line with previous studies; MCW images are significant in establishing a diagnosis of osteoporosis in breast cancer patients who are on aromatase inhibitor therapy; the therapy has the side effect of reducing circulating estrogen levels, which can affect PTH levels.[12,15,16]

Another result of this study was that no significant relationship was found between the picture of MCI and the results of BMD (T-score). This study's results align with a previous study, which found that the MCI picture was not significantly related to patients with CKD. Still, PTH levels were significantly associated with the trabecular bone pattern. This is due to decreased mineral levels in cancellous bone as an effect of a faster increase in PTH than cortical bone.[17] However, this study shares similarities with a previous analysis, as PTH levels are related to the MCI picture. Therefore, the panoramic radiographic image in the form of MCI can serve as a marker in CKD patients, particularly in calcification and resorption processes.[18] According to a previous study, the use of MCI can be used as screening for osteoporosis in the field of panoramic radiographs; in this study, there were significant results on MCI examination in menopausal female patients.[19]

The discrepancy between our findings and those of other researchers may be attributed to the number of patients examined, patient samples, and differences in the measurement areas of the mandibular bone. It could also be influenced by the treatment of patients who received biphosphonate therapy, which has become a significant clinical intervention for osteoporosis due to the ability of biphosphonates to suppress osteoclast activity and thus slow bone resorption selectively.[20]

This study has several limitations, including the subject examination period of only 2 months. It is necessary to allocate a more extended period to accommodate more research subjects. There is a lack of specification regarding the duration of CKD disease that patients have suffered from, and this study also did not analyze the relationship using age range groups due to the small sample size and inadequate distribution of samples per age range group.

This study employed a cross-sectional design with a single data collection point and did not compare its results with those of a healthy population. Therefore, standardized standards could not be established. This study did not analyze the relationship by age group due to the small sample size and inadequate distribution of samples across age groups. Dr. Soetomo General Academic Hospital is a tertiary health facility serving as a referral center. The existence of therapy at the primary health facility and initial treatment at Dr. Soetomo General Academic Hospital makes it difficult for researchers to exclude the influence of medical treatment that patients have received, which can obscure the results of the analysis.

Conclusions

The PMI, MCW, and MCI measurements on panoramic x-ray examinations are not related to the results of BMD examinations in patients with end-stage renal disease. Therefore, employing these three measurements as a standard for osteoporosis screening using panoramic x-rays is not feasible.

Conflict of Interest

The authors have no conflicts of interest to declare.

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