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Evaluation of the diagnostic accuracy of CT scan of the abdomen and thorax compared with DXA as the standard reference in patients with suspected osteoporosis

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Abstract: Osteoporosis is the most widespread metabolic bone diseases, which can reduce bone strength and increases risk of bone fracture. Diagnostic methods have been improved in recent decades in a way that the disease are diagnosed prior to the fracture. The basis of diagnosis is Bone Mineral Densitometry (BMD) measurement, which is defined by WHO Committee. A small number of studies have been carried out on BMD using findings of MDCT. This study intends to examine BMD of persons over 50 years old of age, by using abdomen and thoracic CT scan and DEXA as a standard reference. This analytic epidemiologic study examines 105 persons aged over 50 years old who referred to magnetic resource imaging center of Imam Khomeini Hospital (Ahwaz, Iran) for thoracic CT scanning (2014-1015). Abdomen and thoracic CT scan is performed by using MDCT (16 slices) in Imam Khomeini Hospital through daily calibration for ensuring precision of spinal CT attenuation, which is an indication of grounded BMD. Hounsfield number of the first lumbar spine (L1 of HU) and spines of L1-L4 are measured in thoracic images and abdominopelvic images by mapping Region of Interest (1cm^2) in trabecular bone of middle level of spine and avoiding spinal venous level. DEXA of the first lumbar spine is performed by using *Osteosys* DEXAMUTT. Then, HU findings of CT scan are compared with DEXA results and are statistically analyzed. Present study patients are 40 normal persons, 48 Osteopenia patients, and 17 Osteoporosis patients. ROC analysis indicates in a case that L1 of Hu is greater than 159.5, the persons are diagnosed as normal. Otherwise, they are Osteopenia and/or Osteoporosis. Where L1 of Hu is greater than 101.5, the persons are diagnosed as normal or Osteopenia. Conversely, they are viewed as Osteoporosis. This result is also true for L2-L4. HU and DXA can e replaced with each other in clinical conditions. Generally, CT scan can effectively diagnose Osteopenia and Osteoporosis especially in females. Risky persons should be studied for preventing unsatisfied consequences such as fracture.

Key Words: Osteoporosis, Bone Mineral Densitometry (BMD), CT scan, DXA, Hounsfield.

Introduction

Osteoporosis is the most widespread metabolic bone diseases, which can reduce bone strength and increases risk of bone fracture. This disease is known as a silent one, which spreads without any symptom and fractures bones with a small level of activity [1-2]. 12 millions of American males and females are afflicted with osteoporosis and at least 40 million suffer from bone densitometry reduction. Outbreak of this disease increases with respect to age and gender (greater outbreak of this disease in women). Males have greater bone densitometry and gradual hormone changes causing bone densitometry attenuation [3-4]. Nevertheless, probability of bone fracture and mortality is greater in males as compared with females, per each standard deviation of bone densitometry attenuation [4-6]. Bone fracture index is Bone Mineral Densitometry (BMD) in parallel with bone matrix such that bone Densitometry is reduced while bone combination remains normal [7]. As mentioned before, bone fracture is a common disease with probability of 3 in females and 1 in males [8]. Although there is no explicit determinant of Osteoporosis in patients, a large number of causes result in subsidiary form of this disease, including medical treatments and some clinical disorders such as hyperparathyroidism, hypothyroidism, serum cortisol concentration, some digestive disorders, etc. [9]. Osteoporosis is a known disease, by which more than 75 million of Europe, Japan, and America are afflicted. Specifically, it annually causes over 3.2 million of bone fracture [8]. Prevention of osteoporosis and its related fractures build foundation of health, life quality, and independence of elders. The most widespread clinical symptom is spine fractures and femur bone. According to WHO reports, Osteoporosis ranks number 4 next to cancer, stroke, and heart attack as regards the main enemies of humans. According to statistics, death caused by osteoporosis is greater than that of cancers [10]. Death caused by osteoporosis in females is greater than or equal to breast cancer and is four times as much as death caused by cervical cancer [11]. This disease is a complicated heterogeneous problem

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with an unknown cause. Nevertheless, impacts of multiple factors such as menopause, inactivity, older age, smoking, corticosteroids, and some nutrition deficiency including calcium and Vitamin D are identified to a great extent [12].

Diagnostic methods have been improved in recent decades in a way that the disease are diagnosed prior to the fracture. The basis of diagnosis is Bone Mineral Densitometry (BMD) measurement, which is defined by WHO Committee [13]. The most common assured method is dual energy X-ray absorptiometry (DEXA). Although this is a standard method for measuring bone densitometry of all body parts, it primarily can measure central bone densitometry such as spinal cord and femur [14]. Most researchers do not view DEXA as cost saving and ever probable [15]. Accordingly, operational, low-cost, and satisfied-resulting methods should be employed. BMD can also be evaluated by other magnetic resource imaging methods such as QCT and ultrasound. Above all, as WHO's accepted definition of osteoporosis is based on DEXA, this method should be used as the standard reference method for BMD measurement, by which other methods can be assessed [16]. Further studies are conducted for finding other effective methods. For patients doing abdomen and thoracic CT scan, BMD screen of lumbar vertebrae can be performed without imaging, radiation, cost-consuming, and time-consuming [18]. In case of precise performance of attenuation measurement of lumbar vertebrae for Osteoporosis diagnosis, this method can increase Osteoporosis screen and reduces need to DEXA. Moreover, concurrent use of MDCT of abdomen and femur can increase clinical value of this method and reduces extra costs [19]. A small number of studies have been carried out on BMD using findings of MDCT. This study intends to examine BMD of persons over 50 years old of age, by using abdomen and thoracic CT scan and DEXA as a standard reference.

Material and Method

This analytic epidemiologic study examines 105 persons aged over 50 years old who referred to magnetic resource imaging center of Imam Khomeini Hospital (Ahwaz, Iran) for thoracic CT scanning (2014-1015). After the patients are informed of the research plan and are regarded as inclusions of the study, they consent in wring to the participation in research. Criteria of omission from the research are history of metabolic diseases and masco-sclatal diseases, the known malignancy, and spinal fractures, which are completely taken into consideration in this study. Additionally, abdomen and thoracic CT scan is performed by using MDCT (16 slices) in Imam Khomeini Hospital through daily calibration for ensuring precision of spinal CT attenuation, which is an indication of grounded BMD. Hounsfield number of the first lumbar spine (L1 of HU) and spines of L1-L4 are measured in thoracic images and abdominopelvic images by mapping Region of Interest ($1cm^2$) in trabecular bone of middle level of spine and avoiding spinal venous level. DEXA of the first lumbar spine is performed by using *Osteosys* DEXAMUTT. The patients are categorized on the basis of T-score:

1. The patients with -2.5> T score of Osteoporosis;
2. Between -2.5 and -1 as stepony;
3. -1< as normal BMD

Then, HU findings of CT scan are compared with DEXA results and are statistically analyzed. Also, findings of the first lumbar spine as the main index are compared with the second, third, and fourth lumbar spines. Finally, after collecting data by using ROC curve, the proper cutting place is determined and sensitivity and positive-negative predictive values are calculated. SPSS and STATA are also applied. It is worth noting that this study is evaluated and confirmed by ethics committee of Ahwaz Medical Science University.

Results

105 patients with mean age of 59.09 years old participate in this analytic epidemiologic study (44 patients: 1 male and 43 females) during abdominopelvic CT scan. Also, 61 patients are examined by doing Thoracic CT scan: (4 males and 57 females). Findings on Hounsfield number of the first-to-fourth lumbar spines in abdominopelvic imaging are as follows:

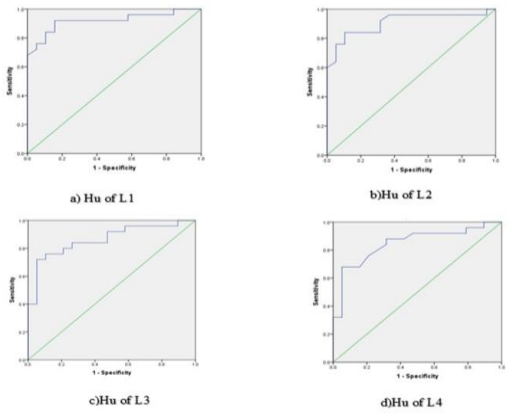

Figure 1: These areas show L1-L4 variables of HU can effectively separate normal persons, Osteopenia, and/or Osteoporosis

Results of ROC analysis and Osteopenia and Osteoporosis diagnosis affected by L1-L4 of Hu are shown. Osteopenia and Osteoporosis patients and normal persons are 25 and 19 in number. Figs 1-4 show ROC. All 4 figures have great areas

under the curve and are statistically significant because the related level of significance are less than 0.05. These areas show that variables of L1-L4 of Hu can effectively separate normal persons from Osteopenia and Osteoporosis patients (Fig 1). Moreover, ROC results of Osteopenia and Osteoporosis diagnosis by L1-L4 of Hu show 6 Osteoporosis patients as well as 38 normal and or Osteopenia persons. Also, separating spots of Osteoporosis, normal, and Osteopenia are illustrated in Table 1. With regard to area of all Hus under the curve, normal and or Osteopenia persons are separated from each other, all of which are displayed in a single ROC (Fig 2).

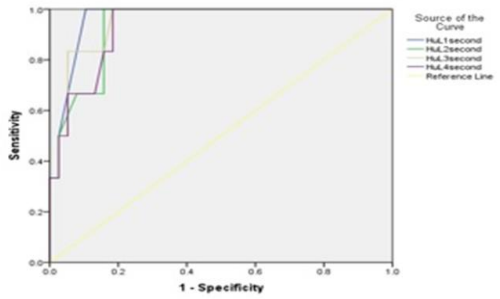

Figure 2: ROC Curve for All concerned variables

Findings on Hounsfield number of the first lumbar spine in abdominopelvic and thoracic imaging are as follows:

Osteopenia and Osteoporosis are analyzed by ROC (L1 of Hu). Osteopenia and/or Osteoporosis patients are 65 in number and normal people are 40 in number. Osteoporosis patients are 16 in number and normal and/or Osteopenia patients are 89 in number (Fig 3).

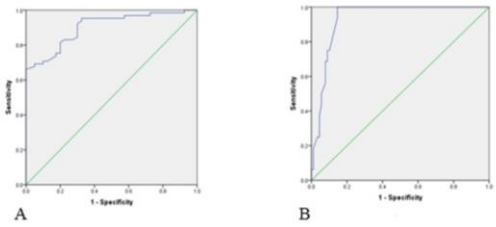

Figure 3: Value of areas below the curve (0.933) is statistically significant because the related level of significance are less than 0.05. These areas show that variables of L1-L4 of Hu can effectively separate normal persons from Osteopenia and Osteoporosis patients. Where L1 of Hu is greater than 101.5, the persons are diagnosed as normal or Osteopenia. Conversely, they are viewed as Osteoporosis. Specifically, Where L1 of Hu is greater than 101.5 in females, they are diagnosed as normal or Osteopenia while others are Osteoporosis.

In analysis of ROC diagnosing Osteopenia and Osteoporosis by L1 of Hu in terms of gender, female Osteopenia and/or Osteoporosis are 63 in number and normal persons are 37 in number. Male Osteopenia and/ or Osteoporosis are 2 and 3 in number respectively. Female Osteoporosis and normal/ Osteopenia patients are 16 and 84 in number. Male normal/ Osteopenia patients are 5 in number. This cannot be illustrated by diagram (Fig 4).

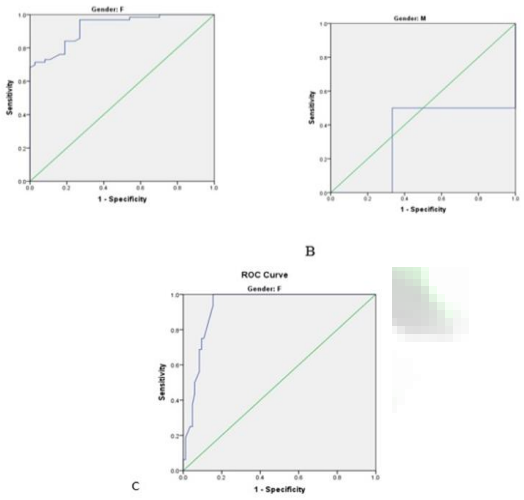

Figure 4: ROC in Terms of Gender. Value of areas below the curve (0.925) is statistically significant because the related level of significance are less than 0.05. L1 of Hu can effectively separate normal persons, Osteopenia, Osteoporosis from each other (a). This value is not statistically significant in males (P-value<0.564) . Accordingly, where L1 of Hu is greater than 159.5 in females, they are diagnosed as normal. Otherwise, they are Osteopenia and/or Osteoporosis. In females, value below the curve is 0.978, which is statistically significant because the related level of significance are less than 0.05. This finding suggests that L1 of Hu can effectively separate normal persons, Osteopenia, Osteoporosis from each other. Where L1 of Hu is greater than 101.5 in females, they are diagnosed as normal or Osteopenia. Otherwise, they are Osteoporosis (c).

In Hu and T score Figure, there is a highly linear correlation between these two variables. Their two diagrams can intuitively diagnose L1 of Hu over Lumbar T Score. A high dash between two lines suggests corresponding diagnosis role of these two variables. This can occur for L2-L4 according to L1 (Figs 5 and 6). Generally, these study patients are 40 normal persons, 48 Osteopenia patients, and 17 Osteoporosis patients (Fig 7).

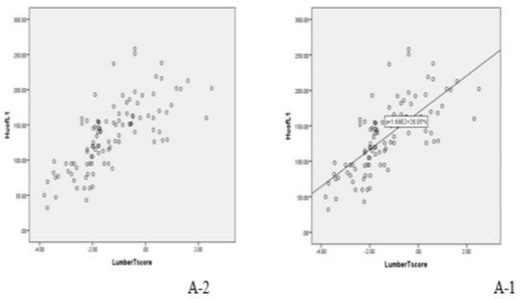

Figure 5(a): Dispersion of L1 relative to Lumbar T Score without regression line shows a high linear correlation between these two variables.

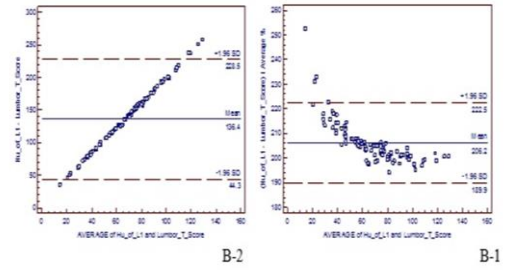

Figure 5(b): These two diagrams can intuitively diagnose L1 of Hu over Lumbar T Score. A high dash between two lines suggests corresponding diagnosis role of these two variables.

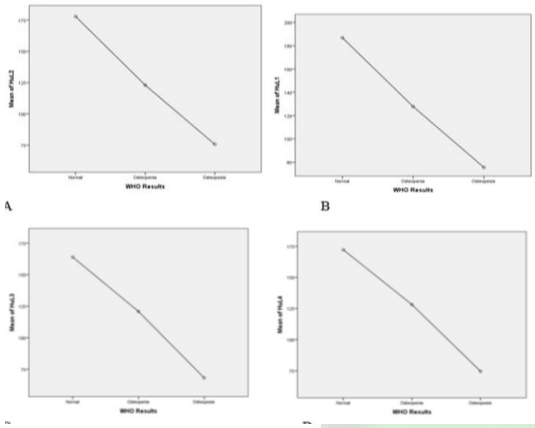

Figure 6: Means of L1, L2, L3, and L4 of Hu

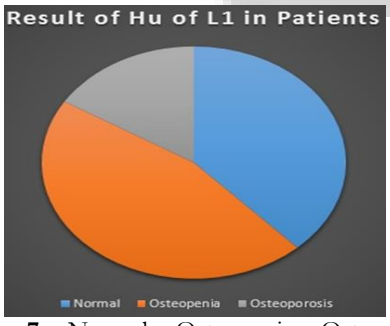

Figure 7: Normal, Osteopenia, Osteoporosis Patients in terms of Hu L1.

Discussion and Conclusion

Findings demonstrate 40 normal persons, 48 Osteopenia patients, and 17 Osteoporosis patients. ROC analysis indicates in a case that L1 of Hu is greater than 159.5, the persons are diagnosed as normal. Otherwise, they are Osteopenia and/or Osteoporosis. Where L1 of Hu is greater than 101.5, the persons are diagnosed as normal or Osteopenia. Conversely, they are viewed as Osteoporosis. Specifically, Where L1 of Hu is greater than 101.5 in females, they are diagnosed as normal or Osteopenia while others are Osteoporosis. This can occur for L2-L4. This study is consistent with some other findings of other researchers. Schreiber *et al.,* (2011) examine 25 patients with mean age of 71.3 years old and find a strong correlation between HU and BMD (T score $P<0.0001$). Additionally, the average HU of normal, Osteopenia, and Osteoporosis patients are respectively 133 (118-147), 100 (93-108), and 78 (61-95) [20]. These results are relatively consistent with this study. Richardt *et al.,* (2013) study 1867 adults during 10 years and reveal that abdomen CT scan can diagnose BMD of normal and Osteopenia patients without any exposure to radiation and any extra cost payment. The threshold of HU 160 or less, there is over %90 sensitivity in the first lumbar spine for subtracting normal persons from Osteoporosis. The threshold of HU 110, there is similarly over %90 sensitivity for subtracting Osteopenia from Osteoporosis. The similar threshold is observed in this study. The positive predictive value of Osteoporosis is %68 or greater in HU threshold below 100 and the negative predictive value of Osteoporosis is %100 (which is statistically significant). Pickhard *et al.,* (2011) demonstrate effectiveness of attenuation measurement of lumbar spine in persons undergoing CT Colonoscopy for BMD screen and its high sensitivity for Osteoporosis as compared with DXA T score. HU 160 is %100 sensitive to Osteoporosis and is customized %46 [19]. Time period of this study is shorter than others and the concerned patients are smaller in number. Further studies are suggested to concentrate on a larger number of persons in longer period of time. Larger number of patients can lead to greater level of generalization about females and males. Generally, CT scan can effectively diagnose Osteopenia and Osteoporosis especially in females. Risky persons should be studied for preventing unsatisfied consequences such as fracture.

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