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A systematic quality assurance study in bone densitometry devices

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Abstract. Osteoporosis is the most common metabolic bone disease and can result in devastating physical, psychosocial, and economic consequences. It occurs in women after menopause and affects most elderly. Dual-energy x-ray absorptiometry (DXA) is currently the most widely used method for the measurement of areal Bone Mineral Density (BMD) (g/cm^2) .DXA is based on the variable absorption of X-ray by the different body components and uses high and low energy X-ray photons. There are two important values in the assessment of the DXA. These values are T-score and Z-score. The T-score is calculated by taking the difference between a patient's measured BMD with the mean BMD of the young normal population, matched for gender and ethnicity, and then by dividing the difference with the standard deviation (SD) of the BMD of the young normal population. T-score and also Z-score are directly depends on the Bone Mineral Density (BMD). BMD measurements should be made periodically in a patient life. But mostly, it is not possible with the same device. Therefore, in this study, for the quality assurance of bone densitometry devices, we evaluated the BMD results measured in the different Bone Densitometry (DXA) devices using a spine phantom.

1 Introduction

Osteoporosis is the most common metabolic bone disease and can result in devastating physical, psychosocial, and economic consequences. It occurs in women after menopause and affects most elderly but may also be found in men and rarely in children. Osteoporosis is an insidious illness [1]. Therefore a patient should be periodically measured bone mineral density (BMD). Dual-energy x-ray absorptiometry (DXA) is currently the most widely used method for the measurement of areal bone mineral density (g/cm^2) because of its low cost, minimal radiation exposure, accessibility, and ease of use. DXA uses two X-ray beams which are different energy levels. These levels contain low and high energy X-rays. Each X-rays pass through specific tissues. If bone, fat or lean tissue components exist, DXA cannot directly estimate the relative proportion of all three components. DXA can directly estimate the proportion of fat and lean tissue without bone. Besides, DXA determines the proportion of bone and soft tissue for structure that contain bone. There are two important values in the assessment of the DXA. These values are T-score and Z-score. T score is used to evaluate bone density on young people moreover Z score is used to evaluate bone density based on age and gender. T-score and also Z-score are directly depends on the Bone Mineral Density (BMD) [2]. In a patient life, BMD measurements have been made several times because of the following procedure of the patient, but mostly it is not possible with the same devices. Therefore, in this study, for the quality assurance of bone densitometry devices, we evaluated the BMD of spine phantom which are measured in the several Bone Densitometry (DXA).

2 Material and Method

In this study, we totally evaluated 23 DXA devices manufactured three different corporations .These DXA devices were in 23 different hospitals located Istanbul, Turkey.

Before the measurements, daily calibrations were made for all devices and measurements were then performed in each hospital. A spine phantom anthropomorphic was used in the measurements. For the phantom, total Area is 52.39 cm^3, total BMC is 52.24 gr and phantom's BMD is then calculated as 0.997 gr/cm^3. After choosing the spine phantom imaging protocol, the phantom values were entered to the device computer as a patient with 20 years old, women patient (some devices accepts as white women, some other devices accepts as Asian women), 50 kg weight and 160 cm height. The phantom was placed in the device bed according to the patient's position and imaging procedures were then performed.

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3 Results and Discussion

Osteoporosis is often occurring silently and patients don't know that they have osteoporosis till their bones suddenly strain or bump. There are certain risk factors linked to development of osteoporosis. It develops quickly therefore BMD values should be measured periodically. World Health Organization (WHO) defines low bone mass and osteoporosis as follows:

1. In case the T-score is in the range of 0 to -1 SD, the subject is healthy;
2. In case the T-score is in the range of -1 to -2.5 SD, the subject is osteopenic (low bone mass);
3. In case the T-score is less than -2.5 SD, the subject is an osteoporotic patient;
4. In case the T-score is less than - 2.5 SD with fragility fracture, the subject is severely osteoporotic. [3]

In this study, we evaluated the BMD results measured in the different Bone Densitometry (DXA) devices using a spine phantom. Two values (Area and BMC) were directly measured by means of the device computer and the values of BMD were calculated by using these measurements values [4-5]. Also Z-score and T-score values of phantom were calculated using BMD values by the device computers using the above formulas;

T-score = (patient's measured BMD - mean BMD of young normal population) / (Standard Deviation of BMD of young normal population).

Table1. Area, BMC, BMD, T-score and Z-score of the first group DXA devices.

Device	Area (cm^2)	BMC (g)	BMD (g/cm^2)	T Score	Z Score
1.Device	52.75	52.99	1.005	-0.40	-0.20
2.Device	52.78	52.82	1.001	-0.40	-0.40
3.Device	52.52	52.23	0.994	-0.50	-0.50
4.Device	52.19	52.27	1.010	-0.30	-0.10
5.Device	51.86	51.52	0.994	-0.50	-0.48
6.Device	52.04	52.04	1.000	-0.40	-0.20
7.Device	51.99	51.76	0.996	-0.50	-0.20
8.Device	51.04	51.68	1.013	-0.30	-0.10
9.Device	51.57	51.65	1.001	-0.20	-0.20
10.Device	50.79	51.57	1.015	-0.30	-0.10

The Z-score is similarly calculated, comparing a patient to age matched group;

Z-score = (patient's measured BMD - mean BMD of age-matched group) / (Standard Deviation of BMD of age-matched group).

Each trademark group DXA devices values (T-score, Z-score and BMC, BMD) for 23 different DXA devices were given Table 1, Table 2, and Table 3. When tables are analyzed it is seen that given values have important different variation for each group DXA devices. In generally, while BMD values of first group DXA devices are close to (0.997 g / cm^3), BMD values of second group DXA devices have higher value than physical BMD value of the spine phantom. On the other hand, BMD values of third group DXA devices have higher value than physical BMD value of spine phantom. When T-scores of the spine phantom are analyzed, T-scores of first group DXA devices are close to each other and the other two groups show the same trend with the first group DXA devices. But when the comparisons are made among the groups, it is seen that there are some alteration among the T-score values. For example, there are 0.6 value difference between third device of the first group DXA devices (-0.5) and third device of the third group DXA devices (0.10). When Z-score is analyzed among the each group DXA devices, similar differences are seen. For example, there are 0.7 value difference between seventh device of first group DXA devices (-0.20) and seventh device of third group DXA devices (0.50).

Table 2. Area, BMC, BMD, T-score and Z-score of the second group DXA devices.

Device	Area (cm^2)	BMC (g)	BMD (g/cm^2)	T Score	Z Score
1.Device	51.70	57.32	1.109	-0.42	-0.37
2.Device	51.02	55.21	1.082	-0.45	-0.42

Table 3. Area, BMC, BMD, T-score and Z-score of the third group DXA devices.

Device	Area (cm^2)	BMC (g)	BMD (g/cm^2)	T Score	Z Score
1.Device	48.74	56.28	1.154	0.00	0.00
2.Device	48.09	55.47	1.153	0.00	0.00
3.Device	48.70	56.20	1.154	0.10	0.10
4.Device	48.77	56.01	1.148	-0.30	-0.30
5.Device	48.47	55.59	1.146	0.00	0.00
6.Device	49.21	56.10	1.138	-0.10	0.40
7. Device	48.66	55.81	1.146	-0.10	0.50
8.Device	48.94	56.19	1.148	0.00	0.00
9.Device	49.26	56.16	1.140	-0.10	0.40
10.Device	48.74	56.43	1.157	-0.30	0.20
11.Device	49.70	56.15	1.129	-0.10	-0.10

4 Conclusion

Osteoporosis has become a chronic disease of our time. This disease should be kept under control. These studies showed that BMD, T-score and Z-score values point out important changes from device to device even using the same phantom. These changes can affect the type of treatment (as osteopenic, osteoporotic, severely osteoporotic) [6]. Therefore, using the same device for the treatment accuracy is extremely important.

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