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Original Article

Effects of clinical reanalysis in dual energy X-ray absorptiometry reports

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ABSTRACT

Objectives: This study aims to assess poor positioning rates of patients during X-ray and the accuracy of the analysis.

Patients and methods: In this study, we reanalyzed 323 dual energy X-ray absorptiometry (DXA) reports, by evaluating the scan images for proper patient positioning and scan analysis. We reviewed reports, according to a checklist prepared considering the proposals of Watts and The International Society for Clinical Densitometry official positions for 2013 (which were the same as in 2015). At least two remaining vertebrae were used to derive new bone mineral density and new T-scores.

Results: Positioning failures were found in 64.7% of the spine X-rays, 60.5% of the hip X-rays, and 83.9% of X-rays of both regions. A total of 112 (34.7%) spinal DXA images needed new T-score adjustments. T-scores and bone mineral density differed between the first reports and the clinician reanalysis ($p<0.001$).

Conclusion: The error rate in DXA reports was higher than expected. Clinician analysis of DXA reports are important. To obtain a quality DXA report, all healthcare professionals should be trained and reminded about this topic.

Keywords: Analysis; dual energy X-ray absorptiometry; errors; positioning.

Before fractures, osteoporosis is a silent disease. Fractures occur with or without trauma and can result in various economic burdens. However, osteoporosis can be prevented, diagnosed and treated before fracture formation. The World Health Organization (WHO) defines osteoporosis using a T-score acquired through dual energy X-ray absorptiometry (DXA) measurements of the hip and spine bone mineral density (BMD), since BMD is a diagnostic classification.[1] The term 'osteoporosis' is used if the T-scores of the lumbar spine and the total hip are -2.5 or less. The term 'osteopenia' is used when the T-score is between -2.5 and -1, and the term 'normal' is used when the T-score is -1.0 and above. The WHO diagnostic criteria may be applied to women during the menopausal transition, but they are mainly used for postmenopausal women and men over 50.[2,3] The BMD is not the primary determinant of the diagnosis, but it is an important aspect of bone strength. Femur neck BMD is used with a fracture risk assessment tool (FRAX) for treatment decisions.[1,4]

The T-scores defined in a DXA report are important for prevention and for treatment recommendations for patients with osteoporosis. Before clinicians dictate the report, a technician has prepared the patient positioning, scan analysis and a scan printout. Clinicians should reanalyze all these stages before reporting. This reanalysis is required for DXA to continue to be considered as the gold standard.[5] However, in daily clinical practice, time limits and patient numbers complicate this process. A technician or a clinician who tries to speed up the process may rely on auto analysis. However, Baniak at al.[6] demonstrated that the use of auto analyzed DXA should be discouraged.

Common errors in BMD testing occur in regards to indication, quality control, acquisition, analysis

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and interpretation. Errors in patient positioning, skeletal site, artifacts removal, and demographic data are considered improper acquisition. When there is inaccuracy in the labeling of vertebral bodies, bone edges, and regions of interest (ROI), these errors are defined as analysis errors.[7] All these steps are important.

A non-optimal process may lead to over diagnosis or under diagnosis.[8] The International Society for Clinical Densitometry (ISCD) and the International Osteoporosis Foundation (IOF) support improved education to promote clinical and scientific advances in the field.[3] Nevertheless, errors are common.[6,7,9] The first purpose of this study was to assess a part of acquisition: the failure to properly position the patient. Our second aim was to assess the accuracy of analysis and interpretation. For these aims, we reviewed 323 DXA reports retrospectively according to the ISCD official positions for 2013.[3,10,11] Because the DXA scan image is used to see whether the patient was positioned correctly, we compared the mean BMD and the mean T-scores between the two analyses. In addition, the diagnostic classifications (normal, osteopenia, and osteoporosis) between the first and second analysis were examined in concordance with WHO standards.

PATIENTS AND METHODS

The DXA reports of postmenopausal women admitted to a Physical Medicine and Rehabilitation Department Trakya University Hospital between 1 January 2014 and 31 July 2015 were examined. Male patient' reports and those reports with inadequate print quality were excluded. Scan images from reports obtained from the Trakya University Hospital Nuclear Medicine Department by using a Hologic DXA machine (Discovery, Hologic Inc., Bedford, MA, USA) were included. A written informed consent was obtained from each patient. The study was conducted in accordance with the principles of the Declaration of Helsinki. The same technician, who was trained in this topic, performed all testing on the same machine.

Poor positioning in scan images of reports was detected according to the recommendations of the ISCD official positions for 2013 (which is the same in 2015) and studies on the topic. According to these standards, we made a checklist to control each stage of positioning and acquisition, as shown in Table 1, and Figures 1 and 2.[3,4,10] Then the DXA scan images were used to confirm proper positioning and analysis.

The posterior-anterior L1-L4 scan images on DXA reports were used to analyze whether the spine ROI was performed correctly. When a wrongly included vertebra, such as T_{12} instead of L1, was detected, the T_{12} was excluded and the BMD of L1, L2, and L3 were included for a new mean BMD calculation. The same procedure was done for vertebrae that were affected by local structural change and were clearly abnormal. More than a 1.0 T-score difference between

Table 1. Check list on scan image for proper positioning and analysis*

	Proper		Improper	
	n	%	n	%
The spine:				
1. The spine is straight on the image.	232	71.8	91	28.2
2. Spinous processes are in centrum. Not rotated.	29	89.8	33	10.2
3. Almost equal soft tissue fields have on either side of the spine.	174	53.9	149	46.1
4. Includes part of the lowest vertebrae with ribs (T_{12})	286	88.5	37	11.5
5. Includes the pelvic brim (L4-L5 interspace, both iliac crests and a part of sacrum).	241	74.6	82	25.4
Lumbar spine regions of interest:				
6. Includes segments of L1-L4.	291	90.1	32	9.9
7. If anatomically abnormal vertebrae have, they are excluded from analysis.	202	62.5	121	37.5
The hip:				
8. The shaft of the femur parallel to the long edge of the table.	254	78.6	69	21.4
9. The lesser trochanter is seeing little or none.	250	77.4	73	22.6
Hip regions of interest:				
10. Include all of the acetabulum.	320	99.1	3	0.9
11. Part of the shaft below the trochanter	312	96.6	11	3.4
12. All of the greater trochanter.	321	99.7	1	0.3
13. The femoral neck box (for Hologic): the inferolateral corner of the box touches the notch where the trochanter and femoral neck juncted. The other three corners are not on bone.	241	74.6	82	25.4

* Prepared in accordance with the ISCD official positions 2013 and Watts suggestions.

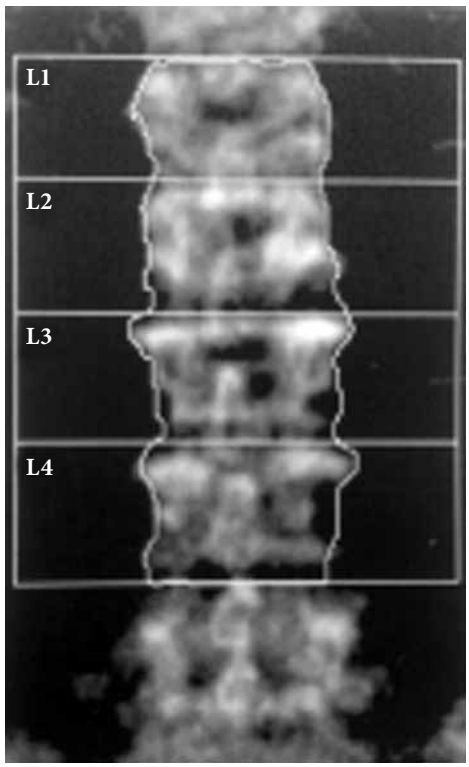

Figure 1. A properly positioned and marked the L1-L4 spine.

the vertebra and the adjacent vertebra was accepted as an abnormal vertebra. At least two remaining vertebrae were used to derive new adjusted BMD and T-scores. When only one vertebra remained, the spine region was accepted as 'non-assessable,' and the diagnosis was based on femoral neck or total proximal femur, whichever was lowest.[3,12] If scoliosis was detected in the spine images, reports were interpreted similarly.[3,5]

Statistical analysis

Poor positioning frequency of the spine and hip was detected using descriptive statistics. We used numbers and percentages for categorical data as descriptive statistics, and we used median (min-max) and the arithmetic mean values ± standard deviation for the quantitative data. Differences between initial and adjusted BMD, as well as total L1-L4 T-score, were evaluated using paired samples t-test. The McNemar test (chi-square) was used to test the differences between initial and adjusted diagnosis based on the WHO classification in all reports. A p value of <0.05 was considered statistically significant. IBM SPSS version 20.0 statistical software (Released 2011. IBM Corp., Armonk, NY, USA) was used for statistical analysis.

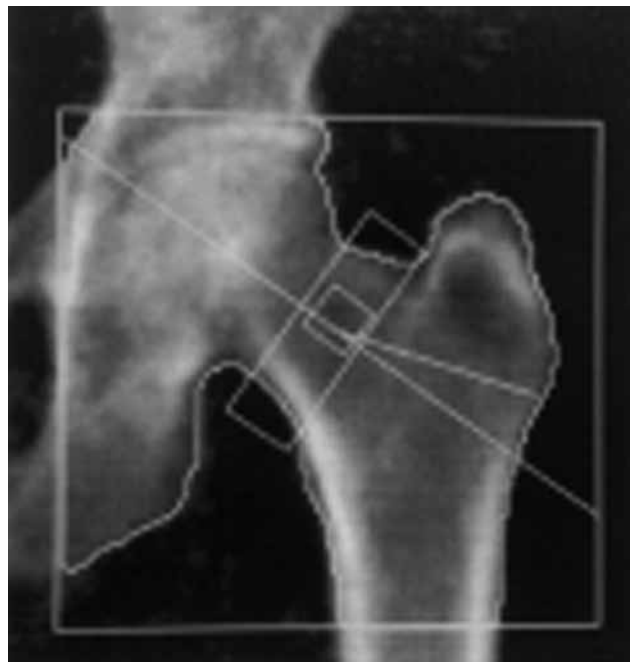

Figure 2. A properly positioned and marked the proximal femur (for Hologic).

RESULTS

The DXA scan images belong to postmenopausal women median age 62.1±8.9 (min 41 - max 84). In 323 images, proper positioning was found with the spine in 35.3% (n=114), with the hip in 39.3% (n=127) and with both regions in 16.1% (n=52). Improper positioning and analysis, according to the checklist, is listed in Table 1.

We found that 9.9% of all images had misplaced boundary lines of the L1-L4 vertebrae, and in 37.5% of all images, abnormal vertebrae were not excluded. Of the 323 spinal DXA images, 112 (34.7%) needed new T-score and BMD adjustments. A total of 195 (60.4%) lumbar spine images did not require the exclusion of abnormal vertebrae. Nine (2.8%) images were unable to be determined from at least two remaining vertebrae; they were accepted as 'non-assessable,' and diagnoses in these reports were based on the hip BMD.

Scoliosis was found in 60 (18.6%) of the images. The initial reports on these images indicated that 12 were normal, 32 were osteopenia, and 16 were osteoporosis. After adjusted analysis, the results were detected as 10 normal, 30 osteopenia and 20 osteoporosis.

A statistically significant difference was found between the initial and adjusted mean BMD and L1-L4 mean T-scores of all reports (p<0.005). The initial and adjusted mean BMD were 0.811±0.137 and

Table 2. Difference between initial and adjusted diagnosis based on the World Health Organization classification in all reports

Initial diagnosis	Adjusted diagnosis				
	Normal	Osteopenia	Osteoporosis	*Total*	*p*
Normal	34	5	0	39	0.160
Osteopenia	1	151	10	162	
Osteoporosis	0	6	116	122	
Total	35	162	126	323	

McNemar-Bowker test.

0.781±0.242, respectively (t=2.694, p=0.007). The initial and adjusted L1-L4 mean T-scores were -2.138±1.251 and -2.199±1.250, respectively (t=3.756, p<0.001). The adjusted mean BMD and L1-L4 mean T-scores were lower than previous values. The WHO diagnoses shown in Table 2 did not change significantly between the initial and the adjusted interpretations (p=0.160).

DISCUSSION

Various stages may affect the reliability of a DXA report,[7] and clinical decisions based on inappropriate DXA reports may be faulty. These results are undesirable not only for patients but also for healthcare providers.

The most important objective for DXA scan images is controlling patient positioning. When reviewing scan images in DXA reports, it is important for clinicians to detect positioning flaws overlooked by technicians.[13] Therefore, we used these images for eliminating position errors in both phases (acquisition and analysis).

Our survey was based on studies that argue positioning affects evaluation results.[4,5,14] Meanwhile, positioning may affect regional body composition results much more than total body DXA measures.[15,16] However, there are also results that indicate fine positioning defects do not create significant BMD changes in clinical densitometry practice.[17,18]

Çetin et al.[9] examined positioning errors in their units and found a high failure rate of 91.1%. In this study, we also found the poor positioning rate to be surprisingly high at 83.9%. Soft tissue fields on either side of the spine were found to be unequal in 46.1% of images. While this situation can be controlled very easily, it was surprising to find that it took first place among poor positioning. The main problem in the hip region was the failure to provide the optimal internal rotation, which occurred in 22.6% of images. Watts[4] reported that the hip positioned with 15-25° internal rotation provides the lowest BMD. In scan images, this hip rotation is reviewed by the shaft, which should be parallel to the edge of the picture, and by seeing little or none of the lesser trochanter. Although this situation is also easy to control, it took fourth place in the ranking of frequency errors.

In the literature review, we observed that technicians produce a false solution for distinct appearances of a small trochanter by leaving some of the trochanter outside of the evaluation due to incorrect boundary line placement. According to Watts,[4] this is the result of poor hip position and should be corrected by having the patient flex the foot before doing the internal rotation, and then relaxing the foot after the strap is in place.

In the error ranking, errors in the lumbar region took the first three places. These errors were unequal soft tissue fields on both sides of the spine, anatomically abnormal vertebrae were not excluded from the analysis and the spine was not straight on the image, respectively. These results supported the study results of Çetin et al.,[9] which found invalid positioning in 61 hip (54.0%) images and 94 spine (83.2%) images. Furthermore, Baniak et al.[6] investigated the precision errors between the auto analysis of images and manual scans and found many errors in the spine than the hip region. Therefore, the lumbar region can be considered a sensitive area in terms of errors.

The hip region's error ranking was a misplaced femoral neck box (25.4%), the shaft of the femur was not parallel to the long edge of the table (21.4%), and too much of the lesser trochanter was seen (22.6%), respectively. The result that the lesser trochanter was seen more than recommended (22.6%) was detected at almost the same rate (24.8%) by Çetin et al.[9] According to Lekamwasam and Lenora[14] external or internal rotation of the leg by 10 degrees from the optimal position results in a decrease or increase in the average BMD, respectively. However, they found that the WHO diagnoses based on T-scores did not change. Similarly, manual analysis for ROI was highlighted in

the study, which detected differences in T-scores but not in the WHO diagnoses based on them.[6]

A clinician should review the scan image for both the patient's proper positioning and scan analysis. In our investigation, we found that abnormal vertebrae were not enough to consider. To the best of our knowledge, there was no data about using scan images for adjusted T-scores. Only Baniak et al.,[6] reported that auto analysis did not exclude abnormal vertebrae and recommended performing it manually. They found that 64.2% of lumbar spine scans were inadequate when auto analysis was used.

In nine scan images of the spine, we found less than the recommended number of evaluable vertebrae; thus, adjusted BMD was not calculated. In these situations, when less than two vertebrae remain, diagnosis should be established in the hip region, which is a different, valid skeletal site.[3]

Scoliosis was detected in 60 (18.6%) spine scan images. Scoliosis patients cannot be positioned with the spine straight on the table. Furthermore, degenerations may lead to invalid measurements of the spine,[5,13] and degenerative changes can elevate spine BMD.[19] As well as for scoliosis, the scan images should also be examined for metal implants, spinal instrumentation, degenerative or metastatic changes, and fractures. In these situations, if only one evaluable vertebra remains after excluding, the spine is reported as 'invalid' and only hip T-scores should be reported.[3,5]

Each adjustment made during the analysis should be recorded. These records are important for further evaluation because the projected spine areas, in serial BMD scans should not manifestly differ. Therefore, patient positioning and scan analysis should be consistent.[12,20] Serial BMD testing can be used to determine an increase or stability in bone density, as well as treatment and response to therapy.[3] Therefore, a change in BMD is important especially for follow-up reports.[12] In our study, we found statistically significant differences between the initial and the adjusted mean BMD and L1-L4 mean T-scores of all reports with reanalysis. This show that analysis is important not only for detection of osteoporosis but also for follow-up to benefit from treatment. However, such a difference was not found in the WHO diagnoses. The difference in T-scores resulted in a different WHO classification in only 15 reports (5.7%). Modifying the WHO diagnoses, therefore, has clinical and individual importance. For instance, a patient who actually was osteopenic may be treated with the diagnosis of osteoporosis, and the unnecessary use of drugs can result in financial and moral losses. Furthermore, a patient who actually was osteopenic may miss the opportunity for treatment. Although this probability is only 5.7%, it should not be ignored.

The limitation of our study was the presumption that reanalysis was 100% accurate. However, aforementioned, the reanalysis was made according to current recommendations on this topic.

In conclusion, our study may show results for only local DXA units, but such assessments are the only way to remain aware of current problems. Therefore, we believe that similar studies should be done in local DXA units with the aim of determining the neglected steps during acquiring and of emphasizing the importance of achieving results from each stage previous to interpretation. We defend the idea that team members should consistently and carefully work to achieve quality in DXA reports. All health professionals involved in this field have essential roles in achieving this goal. We believe that our study will serve as a guide in this area and contribute to reduce errors. Manual analysis should be preferred, and healthcare professionals using DXA should be trained and reminded about this topic.

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