Archives of Osteoporosis (2020) 15:6
https://doi.org/10.1007/s11657-019-0673-3

ORIGINAL ARTICLE

Common errors in dual-energy X-ray absorptiometry scans in imaging centers in Ecuador

Genessis Maldonado[1] · Maria Intriago[1] · Maria Larroude[2] · Gabriel Aguilar[3] · Mario Moreno[4] · Jose Gonzalez[5] · Sara Vargas[6] · Claudia Vera[7] · Karla Rios[1] · Carlos Rios[8]

Received: 28 May 2019 / Accepted: 21 November 2019

Abstract

Summary Dual-energy X-ray absorptiometry is recognized for measuring bone mineral density. The lack of knowledge can lead to errors both in the acquisition of information and in its analysis and subsequent interpretation. The main errors in Ecuadorian Centers were positioning of the patient to the equipment and incorrect analyzed area.

Purpose/introduction Dual-energy X-ray absorptiometry (DXA) is recognized as the gold standard for measuring bone mineral density (BMD) with acceptable errors, good precision, and reproducibility. However, the training of operators in different centers and countries is not standardized, and the lack of knowledge can lead to errors both in the acquisition of information and in its analysis and subsequent interpretation. The purpose was to determine the most common errors in the performance of bone densitometry from different imaging centers in Ecuador.

Methods Cross-sectional descriptive study. We collected DXA scans from different imaging centers in Ecuador. Data from the DXA scan included city of origin, type of specialist that requested it, and densitometry diagnosis. The DXA images provided were analyzed double blind by experts in the field from Argentina.

Results From a total of 141 patients with a mean age of 61 ± 10 years, 93.6% were women. About 78% of the DXA scans came from private imaging centers and 22% from public centers, 95% of all came from the city of Guayaquil. The machines used were Hologic 50.4% and Lunar 49.6%. The densitometric diagnosis was 16.3% normal, 46.1% osteoporosis, and 37.6% osteopenia. A total of 112 left hip and 49 right hip scans were analyzed from which 31.2% and 22.4% had errors in patient positioning, respectively, mainly internal or external rotation. About 140 lumbar scans were analyzed from which 21.4% had patient positioning errors (not centered or not straight). Also in 38.5% the vertebral area did not correspond to L1-L4. About 3.5% had artifacts such as a metal bar or implant. The region of interest was misplaced in 24.1% of the lumbar scans and 19.9% of the femur.

Conclusions DXA quality standards exist but are often not implemented in clinical practice. When studies are performed incorrectly, it can lead to important errors in diagnosis and therapy. Physicians interested in the management of osteoporosis, although not directly involved in the performance and interpretation of DXA, should be familiar with the protocols to minimize errors and allow the proper use of bone densitometry.

Keywords DXA · Ecuador · Imaging centers · Osteoporosis · Osteopenia

✉ Genessis Maldonado
genesismaldonadovelez92@gmail.com

Maria Intriago
majointriagow@gmail.com

Maria Larroude
mariasilvia.larroude@gmail.com

Gabriel Aguilar
aguigabriel@gmail.com

Mario Moreno
mjmadoctor@hotmail.com

Jose Gonzalez
jgonzalezdr@hotmail.com

Sara Vargas
drasaravargas@gmail.com

Claudia Vera
claudiaveraba@gmail.com

Karla Rios
karlariosmoreno@gmail.com

Carlos Rios
criosacosta@gmail.com

Extended author information available on the last page of the article

Published online: 02 January 2020

Introduction

Osteoporosis is a metabolic disorder characterized by low bone mass and deterioration of the bone microarchitecture, with a subsequent increase in bone fragility and susceptibility to fracture [1]. This poses a serious problem for public health due to its high prevalence and the costs associated with its comorbidity. It is estimated that osteoporosis affects more than 200 million women in the world and causes 8.9 million fractures per year, with an average of one fragility fracture every 3 seconds [2].

The World Health Organization bases the definitions of osteopenia and osteoporosis on the results of bone mineral density (BMD). The T score compares the patient's BMD with the reference mean for a young adult. A T score between − 1.0 and − 2.5 defines osteopenia and less than or equal to − 2.5 osteoporosis [3]. Dual energy X-ray absorptiometry (DXA) is recognized as the gold standard for measuring bone mineral density. DXA allows the measurement of BMD in multiple skeletal sites, has been shown to be safe, is easy to use, and requires a short investigation time [4].

Despite the advantages of DXA, the rapid growth of this technique and the lack of standardized training of technologists have raised concerns regarding the quality of DXA studies. In a survey on the perceptions of the quality of DXA reports among 6000 members of the International Society for Clinical Densitometry, 71% of the doctors and 45% of the technologists reported having seen an incorrect interpretation of DXA at least once a month [5]. Likewise, 98% of the doctors considered that bad quality reports were harmful for patients' care.

Several authors have studied the prevalence of errors in densitometries, finding values that fluctuate between 40 and 90%. In one study, of 485 DXA analyzed, only 7% did not present any error, while 74% had an error, 16% two errors and 3% three errors [6]. Another study analyzed DXA scans from 20 diagnostic centers and estimated an overall error rate of 31.8% for the lumbar spine and 49.0% for the femur [7]. The prevalence of errors was even higher in the study by Binkley et al. with 57% for the spine and 90% for the hip [8].

Errors in DXA are divided into four categories: indication, acquisition, analysis, and interpretation [7]. Acquisition errors are the main limiting factor and include incorrect demographic information, improper patient positioning, inappropriate scanning, invalid skeletal site, and the presence of artifacts [9]. Errors in analysis include poor delimitation of the vertebral bodies, bony margins, and regions of interest [10].

Objective

To determine the most common errors in the performance of DXA in different imaging centers of Ecuador.

Methods

A cross-sectional study was carried out. We included DXA scans that had been requested by rheumatologists from different centers of Guayaquil during a 1-month period, from August to September 2017. All available scans of lumbar spine and/or hip were included. Forearm measurements, total body measurements, and measurements taken in children were excluded.

The demographic data of the patients included age, sex, weight, height, body mass index (BMI), clinical diagnosis, and age of menopause for women. From each DXA, the center of origin, T score results, and densitometric diagnosis were included.

The DXA images were analyzed by a radiologist trained on the principles and standards of DXA scanning according to the International Society for Clinical Densitometry (ISCD). Four aspects were studied: scanning, positioning of the patient, delimitation of the region of interest (ROI), and presence of artifacts. The DXA was considered correct if it fulfilled with the following criteria [11]:

Lumbar spine:

Scanning: the image includes part of the lower vertebra with ribs that is usually T12 and the iliac crests that correspond to the upper part of L5.
Position: the spine is straight and aligned with the longitudinal axis; the spinous processes are centered and not rotated.
ROI: ranges from L1 to L4, and the horizontal lines pass through the intervertebral spaces.

Hip

Scanning: the ischium, head of the femur, neck, greater trochanter, and part of the femoral axis under the trochanter can be observed.
Position: the lower extremity is in internal rotation of 15 to 30° in such a way that the lesser trochanter is minimal or not visible and the femoral axis is straight and parallel to the edge of the image.
ROI of the femoral neck: the middle line is centered. The femoral neck box is located in the narrowest part (Lunar) or in the most distal part (Hologic) and does not include any region of the ischium or greater trochanter.

The data was analyzed using the program SPSS v22. Descriptive measures including frequencies, means, and standard deviation were obtained.

Results

Of a total of 141 DXA scans analyzed, 93.6% were from women and 6.4% men with an average age of 61 ± 10 years.

The mean age for men was 63 ± 7 years, and all of them were older than 50 years. The mean age for women was 61 ± 11 years and all of them were postmenopausal. The mean age of menopause was 48 ± 3 years.

The mean weight of the patients was 64.3 ± 10.3 kg, with an average height of 1.5 ± 0.1 m. According to the BMI, underweight was found in 0.7%, ideal weight 26.9%, overweight 44.0%, and obesity 28.4%.

Regarding the clinical diagnosis, 54.6% had osteoarthritis, 9.9% rheumatoid arthritis, 2.1% psoriatic arthritis, and 33.4% other diagnoses.

About 76.6% of the scans came from private centers and 23.4% from public centers. About 50.4% were done with the Lunar equipment and 49.6% Hologic; 48% used the Combined NHANES/Lunar data as the reference standard, and 52% used the NHANES III data. The majority of the scans, 63.9%, measured the BMD in the left hip and lumbar spine. The other combinations of DXA orders are shown in Table 1:

Based on the T score results, 16.3% of the patients had a normal BMD, 46.1% osteopenia, and 37.6% osteoporosis. Table 2 shows the measurements obtained.

We analyzed 112 scans of left hip and 49 of right hip, of which 31.2% and 22.4%, respectively, had errors in patient positioning due to excessive internal or external rotation. The scan did not include the required areas in 8.6% of the DXA. In addition, the region of interest was poorly defined in 20.1% of the cases (Figs. 1 and 2).

Regarding the lumbar spine, 140 scans were analyzed, of which 21.4% had errors in patient positioning since the spine was not centered or was not straight. The scanning was not adequate in 17.9% of the cases. In 38.5%, the selected ROI did not correspond to the vertebrae L1-L4 (Fig. 3).

Metal artifacts were found in 3.5% of the DXA scans. In addition, 22.9% of patients had osteoarthritic changes in the spine and 0.7% scoliosis (Fig. 4).

Based on these errors, it was determined that 40.4% of DXA scans studied were not adequate for BMD assessment. Of these, 10 had T scores within the normal range, 23 in the range of osteopenia, and 24 osteoporosis, which corresponds to 7.1%, 16.3%, and 17.0% of the total population, respectively.

Table 1 BMD sites of measurement

BMD sites of measurements	%
Spine + left hip + right hip	15.6%
Spine + left hip	63.9%
Spine + right hip	18.4%
Left hip only	–
Right hip only	0.7%
Lumbar spine only	1.4%

Table 2 T scores from different measured sites

T score	Mean	Standard deviation
Left femoral neck	− 1,4	0,9
Right femoral neck	− 1,1	0,9
L1	− 1,2	1,4
L2	− 1,5	1,3
L3	− 1,1	1,6
L4	− 0,9	1,8

Discussion

The results of this study show a high prevalence of errors in DXA since 40.4% of the analyzed scans were not considered adequate, which is similar to that found by Tuna et al. of 34.7% [10]. On the other hand, other studies have shown a prevalence of errors in densitometry of up to 93% [6–8].

The International Society for Clinical Densitometry recommends the measurement of BMD for the diagnosis of osteoporosis in the posteroanterior spine and right or left hip indistinctly [12]. In this study, in 82.3% of the reports, the BMD was measured in the spine and hip. A study on the reporting practices of 270 densitometry centers found that 71% of the centers also measured spine and femur; 13% measured only 1 site, and 11% measured the spine, femur, and forearm [13].

The ISCD also recommends the use of T score in postmenopausal women and men age 50 years or older and Z scores in premenopausal women and men younger than 50 years [12]. Since all the patients included in this study were men over

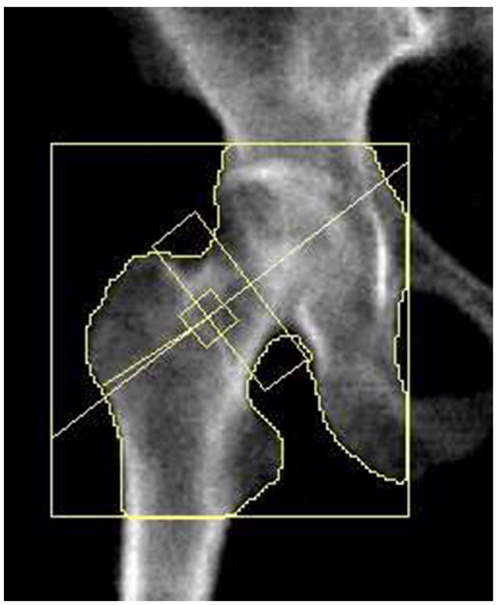

Fig. 1 Position error in hip: a large and pointed lesser trochanter is observed due to inadequate rotation. Also, the global region of interest is not placed correctly

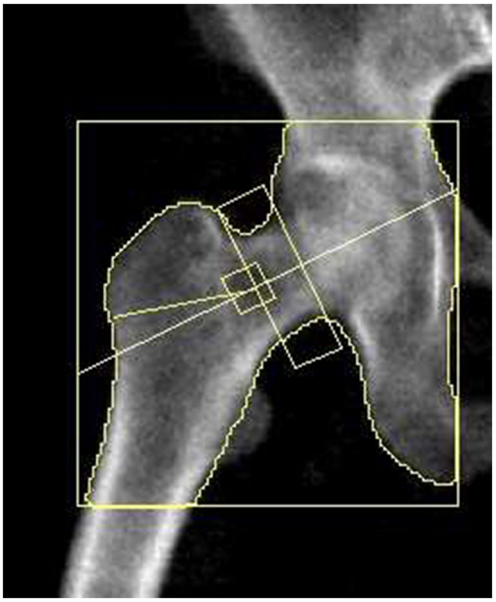

Fig. 2 Position error in hip: the femoral axis is abducted; also, the global region of interest is not placed correctly, and the area of the lesser trochanter is not delimitated within the bone edge detection

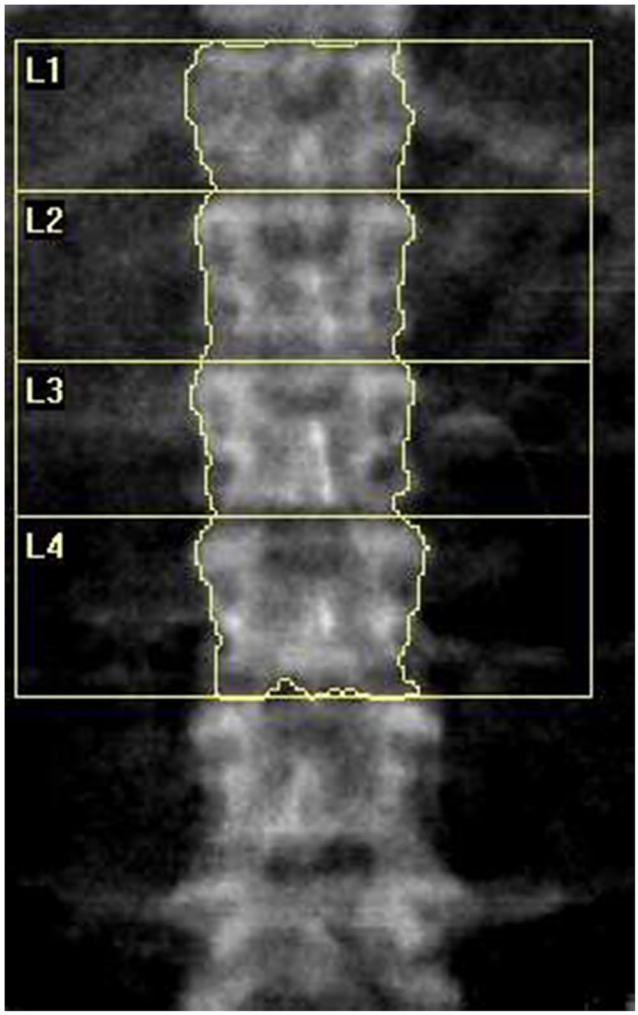

Fig. 3 ROI error in lumbar spine. L1 is placed in T12 where ribs are observed which leads to incorrect enumeration of the vertebrae

50 years and postmenopausal women, the T score was correctly used for the interpretation of BMD.

Baniak et al. compared DXA scans performed by auto-analysis to those done by manual analysis by a technologist and found that the manual analysis was more precise [14]. This emphasizes the role that technologists have in the process of acquiring DXA but in turn implies that the majority of errors in DXA are operator dependent. In their study, 64.2% of the spine scans and 58.6% of the femur were considered inadequate; the most frequent errors were the placement of the ROI in an area other than L1-L4, intervertebral lines that cut the vertebral bodies and the incorrect placement of the femoral neck box [14]. Karahan et al. found that the most frequent spine error was also in the definition of the region of interest, while for the hip, it was inadequate internal rotation [7]. These errors are similar to those found in the present study.

Binkley et al. found that 72% of the errors in DXA are due to wrong positioning of the patient [8]. Two studies had a higher rate of position errors, with 83.9% and 91.1%, respectively [10, 15]. In the first study, 46.1% of the spine scans were not centered, and 22.6% of the hip scans did not have the optimal internal rotation [10]. In the second study, the spine was not straight in 48.7% of the images, and the femoral axis was deviated in 40.7% of the cases [15]. In this study, the percentage of positioning errors was lower with 31.2% for left hip, 22.4% right hip, and 21.4% lumbar spine.

It has been shown that errors in positioning alter the results of BMD. Lekamwasam et al. determined that external hip rotation increases the BMD of the femoral neck by 0.005 g/cm2, while an excessive internal rotation decreases it by 0.009 g/cm2 [16]. Likewise, Rosenthall demonstrated that placing the hip in a more neutral position produces an increase in femoral neck BMD in 65% of patients [17].

Poor rotation also influences the BMD of the lumbar spine, with a reduction of about 20% in bone density when the spine is rotated 60 degrees [18]. This association should be considered when performing DXA studies in patients with scoliosis. Izadyar et al. showed that when the degree of lateral and axial rotation of scoliosis increases, the BMD decreases by 10.8% and 9.6%, respectively [19].

Scanning errors were more common in the spine with 17.9% than in the hip with 8.6%. This is similar to another study where many of the lumbar scans did not include the recommended areas; 38.9% of the images did not show the iliac crests, and 40.7% did not include T12 and L5 [15].

Inadequate placement of the regions of interest is another important source of errors. In this study, the ROI was poorly defined in 20.1% of the hip scans and 38.5% of the spine. Similar data was found in the study by Messina et al. where the most frequent error in the spine was the inclusion or

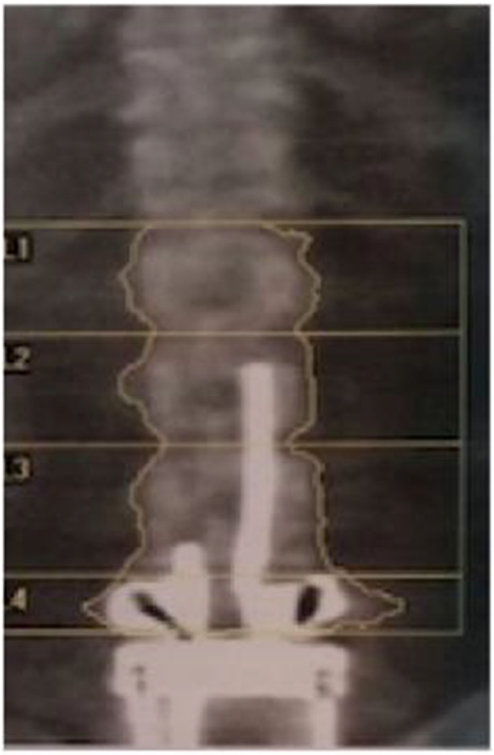

Fig. 4 Metal artifact in lumbar spine

exclusion of vertebrae in 46% of the cases and in the femur was the poor definition of the analysis box in 30% [6].

Adequate delimitation of the ROI is essential in the hip since there is a gradient in the BMD along the femoral neck, with the proximal being the highest and the distal the lowest [20]. Regarding lumbar spine, Peel et al. showed that erroneous labeling of T12 as L1 results in a decrease in BMD, whereas when L2 is labeled as L1, there is an overestimation of BMD [21]. Due to the great variability that exists in the vertebral segmentation and rib positioning, the correct delimitation of the ROI and enumeration of the vertebrae represent a real challenge.

Another of the errors found was the presence of artifacts such as metal bars and severe arthritic changes. Garg et al. showed that certain artifacts such as clips, zippers, coins, and stones produce an increase in BMD [20]. The same effect is seen with the presence of osteophytes, syndesmophytes, and fractures. The magnitude of the increase in BMD by osteophytes varies from 9.5% to 13.9% according to the study by Rand et al. [22]. In our study, more than half of the patients had osteoarthritis as the main diagnosis, and 22.9% presented arthritic changes in lumbar spine, which was similar to the study by Paiva et al. who found a prevalence of lumbar osteophytes of 33.3%, with a correlation with higher bone mineral density [23].

Errors in DXA produce significant variations in BMD and T scores, as demonstrated by the study by Tuna et al. [10]. These authors adjusted the DXA reports based on the most common errors and found a significant difference in the BMD and the T score between the initial and the adjusted report. The mean initial BMD in their study was 0.811 and after adjustment it was 0.781. Likewise, the initial T score was −2.138 and decreased to −2.199. However, there was no significant change between the initial and adjusted densitometric diagnoses.

In the present study, about half of DXA scans were not considered adequate for the interpretation of BMD; of these, the majority with T scores is in the range of osteopenia and osteoporosis. Since this was a cross-sectional study, we have no data on the proportion of scans that were incorrectly interpreted in the clinical practice. Nor could we see if there was any change in the T scores when performing densitometry correctly in patients whose initial DXA scans had errors.

Conclusion

This is the first study of DXA errors in our country, and, as in other countries, the prevalence of errors is high. More studies analyzing the quality of DXA scans in other diagnostic centers in the country and the world are needed to determine how the process of data acquisition is being carried out. It is necessary to achieve a good quality in the DXA reports, so we highly recommend that technologists and doctors should receive the appropriate training.

The limitation of this study is based on the fact that the analysis of DXA is subjective, which is why it is not 100% accurate. For this reason, it is suggested that when analyzing DXA reports, more than one expert should be involved. We hope that this study will serve as a guide in this area and help reduce common errors in densitometry.

Author's contribution *Study conception and design*: Ríos C, Maldonado G.
Acquisition of data: Maldonado G, Intriago M, Larroude M, Aguilar G, Moreno M, Gonzales J, Vargas S, Vera C, Rios K.
Analysis and interpretation of data: Maldonado G, Rios C.
Drafting of manuscript: Intriago M, Maldonado G.
Critical revision: Rios C, Maldonado G, Aguilar G, Larroude M.

Compliance with ethical standards

Conflicts of interests Maria Intriago, Genessis Maldonado, Maria Larroude, Gabriel Aguilar, Mario Moreno, Jose Gonzalez, Sara Vargas, Claudia Vera, Karla Rios, and Carlos Rios declare that they have no conflict of interest.

References

1. Kanis JA, McCloskey EV, Johansson H, Oden A, Melton LJ 3rd, Khaltaev N (2008) A reference standard for the description of osteoporosis. Bone. 42(3):467–475
2. Johnell O, Kanis JA (2006) An estimate of the worldwide prevalence and disability associated with osteoporotic fractures. Osteoporos Int 17(12):1726–1733

3. Kanis JA, Melton LJ III, Christiansen C, Johnston CC, Khaltaev N (1994) The diagnosis of osteoporosis. J Bone Miner Res 9(8):1137–1141
4. Blake GM, Fogelman I (2007) The role of DXA bone density scans in the diagnosis and treatment of osteoporosis. Postgrad Med J 83(982):509–517
5. Lewiecki EM, Binkley N, Petak SM (2006) DXA quality matters. J Clin Densitom 9(4):388–392
6. Messina C, Bandirali M, Sconfienza LM, D'Alonzo NK, Di Leo G, Papini GD, Ulivieri FM, Sardanelli F (2015) Prevalence and type of errors in dual-energy X-ray absorptiometry. Eur Radiol 25(5): 1504–1511
7. Karahan et al (2016) Common mistakes in the dual-energy X-ray absorptiometry (DXA) in Turkey. A Retrospective Descriptive Multicenter Study. Acta Med (Hradec Kralove) 59(4):117–123
8. Binkley N, Krueger D, Hansen K, Siglinsky E, Libber J, Buehring B (eds) (2016) Error prevalence in DXA performance and reporting: improving DXA quality is essential. J Clin Densitom 19(4):532
9. Watts (2004) Fundamentals and pitfalls of bone densitometry using dual-energy X-ray absorptiometry (DXA). Osteoporos Int 15:847–854
10. Tuna F, Yavuz S, Demirbağ Kabayel DD, Sarıkaya A (2017) Effects of clinical reanalysis in dual energy X-ray absorptiometry reports. Turk J Phys Med Rehabil 63(3):201–206
11. Choplin R, Lenchik L, Wuertzer S (2014) A practical approach to interpretation of dual-energy X-ray absorptiometry (DXA) for assessment of bone density. Curr Radiol Rep 2:48–12. https://doi.org/10.1007/s40134-014-0048-x
12. Leib ES, Binkley N, Bilezikian JP, Kendler DL, Lewiecki EM, Petak SM (2006) Position development conference of the International Society for Clinical Densitometry. Vancouver, BC, July 15-17, 2005. J Rheumatol 33(11):2319–2321
13. Fuleihan GE, Stock JL, McClung MR, Saifi G (2002) A national random survey of bone mineral density reporting in the United States. J Clin Densitom 5:3–9
14. Baniak N, Grzybowski S, Olszynski WP (2014) Dual-energy X-ray absorptiometry scan autoanalysis vs manual analysis. J Clin Densitom 17(1):97–103
15. Cetin A, Ozgüçlü E, Ozçakar L, Akinci A (2008) Evaluation of the patient positioning during DXA measurements in daily clinical practice. Clin Rheumatol 27:713–715
16. Lekamwasam S, Lenora RS (2003) Effect of leg rotation on hip bone mineral density measurements. J Clin Densitom 6(4):331–336
17. Rosenthall L (2004) Range of change of measured BMD in the femoral neck and total hip with rotation in women. J Bone Miner Metab 22(5):496–499
18. Giraradi FP, Parvataneni HK, Sandhu HS, Cammisa FP Jr, Grewal H, Schneider R et al (2001) Correlation between vertebral body rotation and two-dimensional vertebral bone density measurement. Osteoporos Int 12:738–740
19. Izadyar S, Golbarg S, Takavar A, Zakariaee SS (2016) The effect of the lumbar vertebral malpositioning on bone mineral density measurements of the lumbar spine by dual-energy X-ray absorptiometry. J Clin Densitom 19(3):277–281
20. Garg MK, Kharb S (2013) Dual energy X-ray absorptiometry: pitfalls in measurement and interpretation of bone mineral density. Indian J Endocr Metab 17:203–210
21. Peel NF, Johnson A, Barrington NA, Smith TW, Eastell R (1993) Impact of anomalous vertebral segmentation on measurements of bone mineral density. J Bone Miner Res 8:719–723
22. Rand T, Seidl G, Kainberger F, Resch A, Hittmair K, Schneider B, Glüer CC, Imhof H (1997) Impact of spinal degenerative changes on the evaluation of bone mineral density with dual energy X-ray absorptiometry (DXA). Calcif Tissue Int 60:430–433
23. Paiva LC, Filardi S, Pinto-Neto AM, Samara A, Marques Neto JF (2002) Impact of degenerative radiographic abnormalities and vertebral fractures on spinal bone density of women with osteoporosis. Sao Paulo Med J 120(1):9–12

Affiliations

Genessis Maldonado[1] · Maria Intriago[1] · Maria Larroude[2] · Gabriel Aguilar[3] · Mario Moreno[4] · Jose Gonzalez[5] · Sara Vargas[6] · Claudia Vera[7] · Karla Rios[1] · Carlos Rios[8]

1 Universidad de Especialidades Espíritu Santo, Km. 2.5 Vía la Puntilla, Samborondón, Ecuador

2 Hospital Cesar Milstein, La Rioja 951, Buenos Aires, Argentina

3 Centro de Diagnóstico Dr. Enrique Rossi, Sanchez de Loria 117, Buenos Aires, Argentina

4 Hospital Luis Vernaza, Loja 700, Guayaquil, Ecuador

5 Hospital Policia Nacional Guayaquil No. 2, Avenida de la Americas, Guayaquil, Ecuador

6 Ecuadorian Society of Rheumatology, Torre Médica Alcívar No. 4. Coronel y Cañar, Guayaquil, Ecuador

7 Universidad Católica Santiago de Guayaquil, Av. Pdte. Carlos Julio Arosemena Tola, Guayaquil, Ecuador

8 Centro de Reumatología y Rehabilitación. Guayaquil, Ecuador, El Oro y Ambato, 1004 Guayaquil, Ecuador