Journal of Clinical Densitometry: Assessment & Management of Musculoskeletal Health, vol. 17, no. 1, 97–103, 2014

1094-6950/17:97–103/$36.00
http://dx.doi.org/10.1016/j.jocd.2013.09.001

Section III: Quality Issues

Dual-Energy X-ray Absorptiometry Scan Autoanalysis vs Manual Analysis

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Abstract

The measurement of bone mineral density (BMD) with dual-energy x-ray absorptiometry (DXA) is valuable for the determination of 10-yr fracture risk and for antifracture treatment follow-up. Ensuring patient scans are performed with accuracy, and reliability is imperative, requiring both technician competence and regular machine calibration. With DXA, analysis of each scan can be performed either with the machine's default autoanalysis or can be optimized manually. For 1 yr, all patients sent for DXA measurements to the Saskatoon Osteoporosis Center had each lumbar spine and hip scan analyzed with both manual and autoanalysis methods and the 2 sets of scans compared. We compared the concordance between the 2 analysis methods by calculating a BMD percent error for all of the scans, with the manually adjusted scans acting as the reference standard. Mann-Whitney *U* tests were completed to test for statistically significance differences between analysis types. In this investigation, scans completed with manual analysis were more accurate with respect to BMD (up to 4.7% error) and T-scores (up to 0.38 difference). In addition, many errors were identified with autoanalysis. Consequently, technicians using DXA should not rely on autoanalysis but rather be trained in and use manual analysis.

Key Words: Autoanalysis; bone mineral density; dual energy x-ray absorptiometry; manual analysis; osteoporosis.

Introduction

Osteoporotic fractures increase morbidity, reduce quality of life, and decrease survival *(1–3)*. Moreover, osteoporosis has a sizable economic impact on both patients and the health care system. In Canada, the average cost of treating a hip fracture over a 1-year period is $46,664, resulting in a nationwide annual cost estimate of $1.65 billion CAD for hip fractures alone *(4)*. In the United States, 40% of white women older than 50 years of age will fracture their hip, vertebrae, or wrist as a consequence of osteoporosis *(5)*. Diagnosing osteoporosis early is crucial for minimizing morbidity.

Dual energy x-ray absorptiometry (DXA) measurement of bone mineral density (BMD) is an integral part of 10-yr fracture risk assessment, either as part of The World Health Organization's (WHO) fracture risk assessment tool (FRAX) or The Canadian Association of Radiologists and Osteoporosis Canada (CAROC) system *(6,7)*. In addition to the BMD, FRAX also takes into account previous fragility fractures, parental hip fractures, current tobacco use, long-term oral use of glucocorticoids, rheumatoid arthritis, causes of secondary osteoporosis, and alcohol consumption to quantitatively establish 10-yr fracture risk *(6)*. CAROC is a simpler fracture risk assessment tool that does not require the user to have access to a computer or portable computing device, integrating information from BMD, sex, age, previous fragility fractures, and use of glucocorticoids to semiquantitatively determine 10-yr fracture risk *(7)*.

There are a number of indications for BMD testing, including women older than 65 yr of age, postmenopausal women younger than 65 yr with risk factors for fracture, men older than 70 yr of age, men younger than 70 yr with risk factors for fracture, adults with a history of a fragility fracture, adults with a disease or taking medications associated with low bone

Received 06/09/13; Accepted 09/05/13.
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mass or bone loss, and anyone being considered for pharmacologic therapy or being monitored while receiving antifracture treatment (8).

A useful metric provided by DXA is the T-score (standard deviation [SD] of the difference of the BMD from the mean BMD of a young adult reference population of the same ethnicity and sex (9)), which is one measure provided by a DXA scan analysis (9). The BMD classification of patients is based on their T-scores, with a BMD T-score $\geq$1 SD being normal, between -2.5 and -1.0 SD being osteopenic (or low bone mass), and ≤ -2.5 SD being osteoporotic (8–11). The International Society for Clinical Densitometry recommends stratification based on the lowest T-score from the lumbar spine, femoral neck, trochanter, or total hip (8,10,11). Of course, the BMD does not solely determine the diagnosis but is a valuable aid in making the clinical diagnosis of osteoporosis. BMD is an important component of bone strength and, along with FRAX or CAROC, is used to guide treatment decisions (9,10). Consequently, incorrectly performed DXA scans can lead to errors in risk stratification and jeopardized patient care (10). Therefore, it is crucial that DXA scans be analyzed with the greatest possible accuracy and precision, with attention given to patient position, analysis technique, and any other sources of error, such as unexpected patient motion and internal or external artifacts (10).

Although certification courses provide valid training for DXA measurement and subsequent analysis (such as those provided by the International Society for Clinical Densitometry), unfortunately not all technicians receive this technical training. As a result, many technicians are self-taught to assess BMD and typically rely on the DXA-supplied autoanalysis to ascertain pertinent measurement regions of interest (ROIs). The autoanalysis software within DXA machines delineates the ROI of the lumbar spine (L1-L4) and hip, but manual adjustments, which are often are required, can be made (12). Appropriate patient positioning is imperative for accurate and reliable BMD measurements (12). As the capability to manually adjust the DXA analysis software requires more education and more technician time, an important question is whether the extra training and time required for the DXA manual analysis provides significantly better accuracy compared with the autoanalysis when used in the clinical setting. In this investigation, a set of patient scans analyzed both with autoanalysis and manual analysis was compared to evaluate the accuracy of DXA autoanalysis at the spine, femoral neck, and total hip sites.

Materials and Methods

All DXA scans were performed with a Hologic DXA model (Delphi W QDR 4500 and Discovery W QDR 4500; Hologic, Bedford, MA) and manufacture-supplied software. For lumbar spine scans, patients are positioned as follows: patients are laid on their back, the spine is straight on the table pad (shoulders should be at the upper scan limit line), the patient's pelvis and shoulders are aligned straight on the table pad and centered to the marks on the table pad, the knee positioner is placed under the patient's lower legs and adjusted by rotating it until the femurs are as vertical as possible (to help reduce the lordotic curve of the lumbar spine), and the patient's arms are placed in the most comfortable position (over head or by his or her sides). For hip scans, the positioning is as follows: patients are laid on their back, the foot positioner is placed under the patient's legs and its center is aligned with the patient's midline, the patient's entire leg (from hip socket to foot) is rotated 25° inward, and the medial edge of the foot is placed against the triangle (foot should be flexed toward the ceiling), the femur is aligned to be parallel with the table edge to provide adequate space for the neck box, and the leg is abducted from the midline of the body to straighten the femur.

Each patient underwent a DXA measurement of the lumbar spine and hip and then each scan underwent 2 analyses: a DXA-driven autoanalysis and a technician manually adjusted analysis. The concordance between the 2 analysis methods was compared. Specifically, the complete analysis, BMD, and T-scores were compared between each set of scans for the lumbar spine, femoral neck and total hip, with percent errors calculated to determine which scans were more accurate.

All autoanalyses were conducted without intervention from the technician. For the manually adjusted analysis, the standard autoanalysis was run to set the general ROIs, but before the analysis was finalized, the technician adjusted the ROI, intervertebral lines (for lumbar spine analysis), femoral neck box (for hip analysis), and rarely the trochanteric line (for total hip analysis). For the lumbar spine, the ROI was inclusive of the first lumbar vertebrae to the fourth lumbar vertebrae (L1-L4). The intervertebral lines could be touching the bone, but not cutting through any part of the bone. For the total hip, the superior and inferior parts of the femoral head needed to be 5 pixels from the boundary line, and the bottom boundary line should be 10 pixels below the lesser trochanter. If the lesser trochanter is not visible, the top and bottom boundary lines should be equidistant from the greater trochanter. The femoral neck box should have its upper right corner anchored to the flexure of the femoral neck whereas the other 3 corners should be free and not touching bone. Finally, the trochanteric line should be above the femoral midline. The position of the femoral midline is constant and not subject to manual alteration.

To make a comparison, a BMD percent error was calculated for all of the scans with the manually adjusted scans used as the standard reference. The manual scans were believed to be more correct than the autoanalyzed scans because the boundary lines and all ROIs were placed in the correct anatomical locations—thus, the manually analyzed scans were considered the gold standard in this investigation. Therefore, a larger percent error corresponded with a greater difference between the autoanalyzed scan and manual scan, and thus a larger inaccuracy in the autoanalyzed scans. Subsequently, the autoanalyzed scans were divided as either adequate or inadequate based on the complete analysis. The adequate scans had a complete analysis identical to the manual scan or had