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Quality in dual-energy X-ray absorptiometry scans☆

Sarah L Morgan [a,*], Ginnie L Prater [b]

[a] Division of Clinical Immunology and Rheumatology, University of Alabama at Birmingham Osteoporosis Prevention and Treatment Clinic, Bone Densitometry Unit, USA
[b] Division of Gerontology, Geriatrics and Palliative Care, The Department of Medicine, School of Medicine, The University of Alabama at Birmingham, Birmingham, AL, USA

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ABSTRACT

Dual-energy X-ray absorptiometry (DXA) is the gold standard for measuring bone mineral density (BMD), making the diagnosis of osteoporosis, and for monitoring changes in BMD over time. DXA data are also used in the determination of fracture risk. Procedural steps in DXA scanning can be broken down into scan acquisition, analysis, interpretation, and reporting. Careful attention to quality control pertaining to these procedural steps should theoretically be beneficial in patient management. Inattention to procedural steps and errors that may occur at each step has the possibility of providing information that would inform inappropriate clinical decisions, generating unnecessary healthcare expenses and ultimately causing avoidable harm to patients. This article reviews errors in DXA scanning that affect trueness and precision related to the machine, the patient, and the technologist and reviews articles which document problems with DXA quality in clinical and research settings. An understanding of DXA errors is critical for DXA quality; programs such as certification of DXA technologists and interpreters help in assuring quality bone densitometry. As DXA errors are common, pay for performance requiring DXA technologists and interpreters to be certified and follow quality indicators is indicated.

1. Introduction/quality in DXA scanning

Dual-energy X-ray absorptiometry (DXA) [1] is the gold standard for measuring bone mineral density (BMD) [2], making the diagnosis of osteoporosis [3,4], monitoring BMD [5], and is used in the calculation of fracture risk [6]. Procedural steps in DXA scanning can be broken down into scan acquisition, scan analysis, interpretation, and reporting. Careful attention to these steps and monitoring for errors should theoretically be beneficial in patient management, while inattention to the steps and errors has the possibility of providing information that would inform inappropriate clinical decisions, generate unnecessary healthcare expenses, and have the potential to harm patients [7,8].

Quality is defined by Miriam Webster [9] as: 1): "how good or bad something is, 2) a characteristic or feature that someone or something has: something that can be noticed as a part of a person or thing and 3) a high level of value or excellence". In the case of DXA scanning, the definition of quality could encompass whether or not there are errors in acquisition, analysis, interpretation and reporting and the extent to which accepted guidelines related to quality control, acquisition, analysis, interpretation and reporting are followed. While the technology of modern DXA scanners makes the process of performing and analyzing DXA scans relatively easy, there may be a misconception that quality DXA scanning requires few special skills [10]. It has been shown that there is a high degree of variability in the skills of technologists who perform scans and clinicians who interpret the results [8]. In this report, we emphasize the importance of DXA quality and provide examples of problems with DXA quality.

2. Technical quality assurance/accuracy and precision

Quality assurance is a program of formal and regular review of each component of DXA scanning to achieve accurate and precise measurements. Quality assurance can be broken down into quality control of the DXA scanner as well as quality control of the examination [11]. Accuracy encompasses systematic errors or trueness (i.e. is the real BMD measured?) while precision encompasses random errors and evaluates the ability to reproduce a bone density measurement [12].

Quality assurance includes developing and following standard operating procedures (SOPs), defining appropriate scanner function and acquisition and analysis. Such SOPs are based on the manufacturer's manual and supplemented by ISCD recommendations [13–15]. DXA scanner calibration for trueness for GE Healthcare (Madison, Wisconsin) and Norland (Swissray USA, Piscataway, NJ) scanners requires a daily calibration scan with a special phantom, while Hologic (Bedford, MA) machines have an internal calibration system. For all machines, the process of calibration makes sure that the machine is operating properly and that software algorithms such as edge detection are working properly. Daily phantom scanning is important for evaluating for a shift or drift in BMD values over time [13,14]. Plots of phantom values

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* Corresponding author at: 830 Faculty Office Tower, 510 20th Street South, University of Alabama at Birmingham, Birmingham, AL 35294-3408, USA.
E-mail address: slmorgan@uab.edu (S.L. Morgan).

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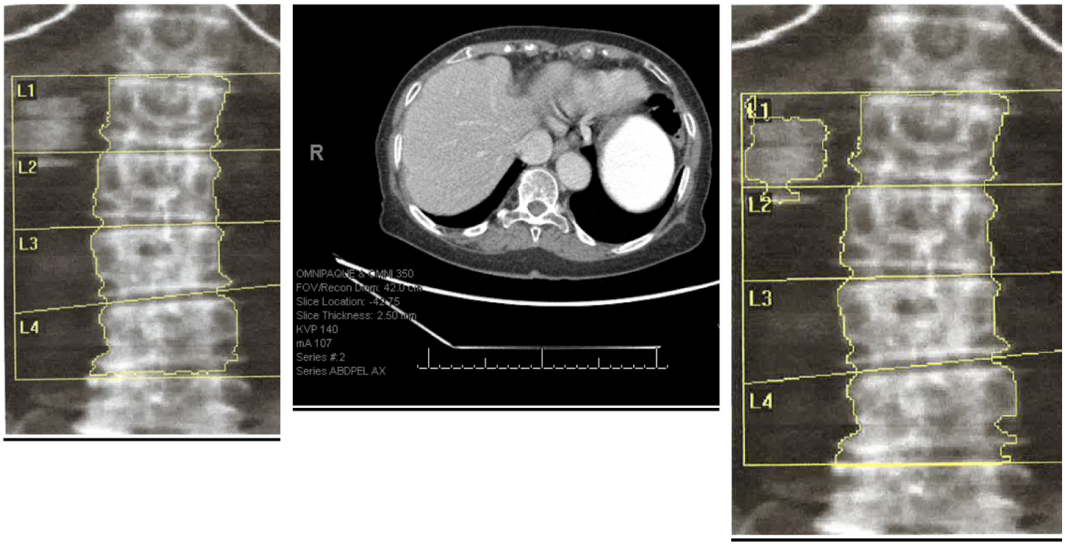

Fig. 1. On the left is the DXA image showing an opacity lateral to L1. In the middle is the CT scan cut documenting that the opacity is a gallstone. On the right is the "undo" view on the DXA scanner showing that the gallstone was recognized by the software (yellow outline) and was omitted from the soft tissue baseline. Therefore, it is correct to leave L1 in the analysis. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

for bone mineral content (BMC), BMD, and area, such as Shewhart control charts, should be completed and evaluated regularly [13,14]. The completion of a precision study by the technologists in a facility, using a representative clinical population, is important to determine how much of a change is real and is a critical part of quality DXA interpretation [16]. Specific guidelines for the performance of a precision study and minimum acceptable precision for a technologist have been published [16–24].

3. Errors in DXA scanning

There are many sources of error and factors that may affect trueness and precision in BMD involving scan acquisition and analysis; these include factors related to the machine, the technologist, and the patient [25].

3.1. Errors and factors affecting trueness and precision related to the machine

Machine errors encompass factors and algorithms within the machine related to scanning, scan analysis and databases [26,27]. It has been determined that the errors introduced by operator and subject variability are generally greater than errors related to machine performance [28].

In a study comparing autoanalysis (no technologist intervention) of DXA scans with manual analysis by a technologist, manual analysis was more accurate related to BMD and T-scores [29]. For one year, on a Hologic scanner, all of the scans at an osteoporosis center were analyzed by both autoanalysis and manual analysis. 64.2% of the lumbar spine and 58.6% of the auto analyzed femur scans were deemed inadequate. The average T-scores were significantly different between the auto analysis and manual analysis at the lumbar spine, total hip and femoral neck. The two most common spine errors using autoanalysis were placement of a region of interest in an area other than L1–4 and intervertebral lines that cut through vertebral bodies in a scoliotic spine [29]. The most common hip errors from autoanalysis were misplacement of the femoral neck box, a trochanteric line placed below the midline and incorrectly placed boundary lines [29].

Choi in 2012 found that machine software algorithms, which should copy the soft tissue region, may not copy it like the previous scan and can cause the calculation of incorrect BMD values and therefore affect diagnostic results [30].

Binkley et al. in 2005 described an unintentional error in a software upgrade for GE Healthcare Encore versions 7.x–8.x [31]. In this update, data from the National Health and Nutrition Examination Survey III was incorporated in to GE Lunar machines and the young-normal reference

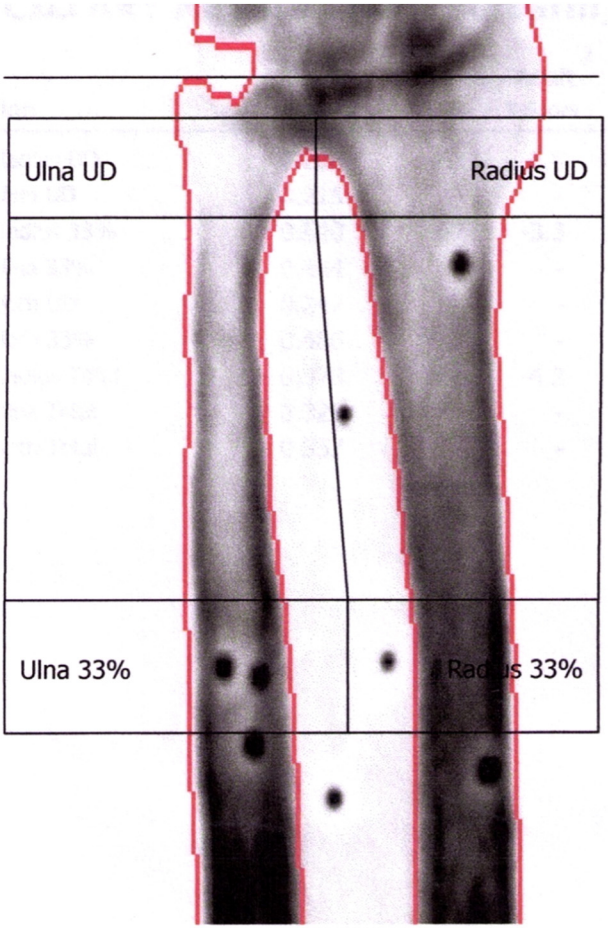

Fig. 2. Shotgun pellets overlying regions of interest are seen on a forearm scan. The presence of the shotgun pellets will overestimate BMD in the 33% radius (1/3 radius) region of interest. This figure is courtesy of Dr. E Michael Lewiecki.

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