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Original article

Calculation of the Least Significant Change Value of Bone Densitometry Using a Dual-Energy X-ray Absorptiometry System

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ABSTRACT

Purpose: The precision error of a bone density meter reflects the equipment and reproducibility of results by an examiner. Precision error values can be expressed as coefficient of variation (CV), CV%, and root mean square-SD (RMS-SD). The International Society for Clinical Densitometry (ISCD) currently recommends using RMS-SD as the precision error value. When a 95% confidence interval is applied, the least significant change (LSC) value is calculated by multiplying the precision error value by 2.77. Exceeding the LSC value reflects a significant difference in measured bone density. Therefore, the LSC value of a bone density equipment is an essential factor for accurately determining a patient's bone density. Accordingly, we aimed to calculate the LSC value of a bone density meter (Lunar iDXA, GE) and compare it with the value recommended by the ISCD. We also assessed whether the value measured by the iDXA equipment was below the LSC value recommended by ISCD. **Material and Methods**: The bone densities of the lumbar spine and thighs of 30 participants were measured twice, and the LSC values were calculated using the precision calculation tool provided by the ISCD (http://www.iscd.org). To check the reproducibility of the measurement, patients were asked to completely dismount from the equipment after the first measurement; the patient was then repositioned before proceeding with the second measurement. **Results**: The LSC values derived using the CV% values recommended by the ISCD were 5.3% for the lumbar spine and 5.0% for the thigh. The LSC values measured using our bone density equipment were 2.47% for the lumbar spine and 1.61% for the thigh. The LSC value using RMS-SD was 0.031 g/cm^2 for the lumbar spine and 0.017 g/cm^2 for the thigh. **Conclusion**: that the findings confirm that the CV% value measured using our bone density meter and the LSC value using RMS-SD were maintained very stably. This can be helpful for obtaining accurate measurements during bone density follow-up examinations.

Key words: Least Significant Change, Coefficient of Variation (CV), CV%, Root Mean Square-SD

Introduction

The measurement of bone mineral densitometry (BMD) is a useful method for early diagnosis of metabolic bone disease and for evaluating the effectiveness of osteoporosis drug administration. Since the development of Single Photon Absorptiometry by Cameron and Sorenson[1] in 1963, this non-invasive method of measurement has been readily and accurately used. There are four major methods used to measure bone mineral density in the diagnosis of osteoporosis: single photon absorption method, dual photon absorption method, dual energy x-ray absorption method (DXA), and quantitative computed tomography [2]. In addition, Neutron Activation Analysis and Compton Scattering Method [3] are available, but these methods are not commonly used clinically. Among the four methods mentioned above, the DXA method has been the most widely used since it was first introduced in 1987 due to its short inspection time and excellent precision [4].

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The basic principle of the DXA method is to calculate bone density by measuring the attenuation degree of the two energy X-rays. This is done by collecting two different energies penetrating the body into the fluorescence detector. As is well known, the degree of attenuation depends on the atomic number of the material being irradiated and the energy of the incident photon. By separating the low-energy and high-energy parts in the detector, it is possible to measure the density of the bone by differentiating it from the density of the soft tissue in the density of the soft tissue [5].

According to a 2021 U.S. CDC report, an average of 19.6%, 13.1% of men, and 27.1% of women over the age of 65 are reported to have osteoporosis [6]. The biggest problem with osteoporosis is fracture deaths in the elderly, According to a 2021 Milliman Research Uptake Report, 1 in 9 patients with a new fracture experienced another fracture within 12 months, and about 245,000 women and 91,000 men died from osteoporosis-related fractures during the year, especially 30% within 12 months if they had a femoral fracture. As such, an accurate diagnosis of osteoporosis is important for older age groups because it is life-related [7].

During follow-up examinations of osteoporosis patients, strict precision is required because the variation in bone density values is very small. In particular, when observing changes in bone density after a certain period of time, it is necessary to distinguish whether the measured value directly reflects the change in bone density in the body or is a measurement error. To know this, the Least Significant Change (LSC) of the bone density meter can be calculated and accepted as a meaningful change only when the measured bone density value exceeds the LSC.

The above LSC value can be regarded as a significant change in the measured bone mineral density, and the LSC value of the bone mineral density equipment is an essential element for accurate diagnosis of the patient's bone mineral density. Therefore, the author calculated the LSC value of the bone mineral density meter (Lunar iDXA, GE) in my hospital and compared it with the ISCD recommended value. We checked whether iDXA equipment is managed below the LSC value recommended by ISCD.

Material and Method

1. Material

Thirty volunteers (male:female =17:13, age: 24±3) who agreed with the purpose and process of the study, without previous osteoporotic fractures of the lumbar spine and femur, endocrine disease, or other diseases affecting bone metabolism, were included.

2. Method

Bone mineral density of lumbar and femoral regions was measured in 30 people using a DXA instrument (iDXA, GE, U.S.A). The bone mineral density was measured by repositioning the participants after they had completely descended from the equipment.

3. Analysis

It is calculated using precision calculation tools provided by ISCD. The precision calculation tool was downloaded from the ISCD website (http://www.iscd.org).

Result

The LSC value using the CV% recommended by ISCD is the following: 5.3 %, the total hip: 5.0 %. The LSC using RMS-SD was a lumbar: 0.031 g/cm^2, total hip: 0.017 g/cm^2.

Table 1. Comparison of LSC value recommended by the ISCD and LSC value of iDXA

	LSC value recommended by the ISCD	LSC value of iDXA
L-spine	5.3%	2.47% (0.031 g/cm^2)
total hip	5.0%	1.61% (0.017 g/cm^2)

The LSC value using the CV% recommended by ISCD is the following: 5.3 %, the total hip: 5.0 %. The LSC using RMS-SD was a lumbar: 0.031 g/cm^2, total hip: 0.017 g/cm^2.

Discussion and result

X-rays passing through a K-edge filter made of samarium, collimator, low-density tabletop, and patient are then absorbed by an energy-sensitive detector.

The Lunar Prodigy system is a bone density equipment that uses the DXA method. There is an X-ray tube located at the rear of the subject. if a 76 kvp tube voltage is applied, the X-rays generated by interaction with tungsten pass through K-edge filter made of cerium. Passing through the subject with an energy of 38-70 KeV, the detector is detected (Fig. 1).

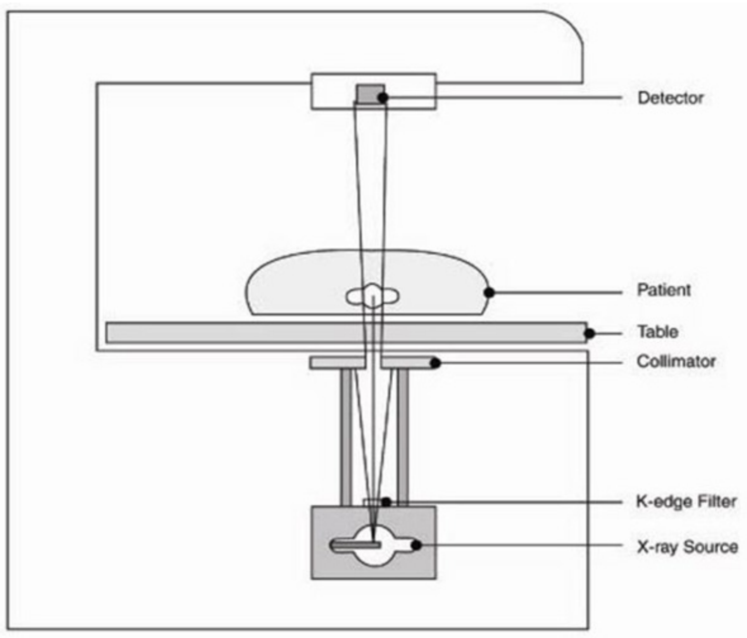

Fig. 1. General feature of bone densitometer based on DXA.
X-rays passing through a K-edge filter made of samarium, collimator, low-density tabletop, and patient are then absorbed by an energy-sensitive detector.

The first-generation DXA equipment uses a single detector with a NaI(Tl) scintillator and a pinhole collimator attached to irradiate the pencil beam. Recently, 16 cadmium-zinc-telluride solid-state scintillator detectors were used and a slit collimator was attached to irradiate the fan beam. Due to this difference, the DXA method shortened the examination time and increased the resolution, but it caused the problem of increased exposure dose for the patient or the operator due to the use of the fan beam. However, the fan beam is now being overcome by using the narrowed fan beam [5].

Factors that can cause errors in the bone mineral density test are excessive obesity and liver disease, more than 30 cm of thickness of the abdomen, the subject's incorrect test position, the wrong lumbar positioning of the examiner, errors in setting the femur region of interest, and mechanical correction of the measuring instrument [8]. Measurement errors occur due to degenerative changes in the skeleton, compression fractures, and aortic calcification. Artificial products of the measuring process and intestinal contrast agents are also causes of error. Radioisotopes can also cause changes in test values.

Bone density meters require higher precision than other medical equipment. In particular, during follow-up examinations of patients with osteoporosis, the change in bone density is very small, so strict precision is required. There are coefficients of variation (CV), CV%, and root mean square-SD (RMS-SD) in the precision error. RMS-SD = (the sum of the SD squares of each subject) / number of subjects, and CV = SD / average. The ISCD currently recommends RMS-SD as a precision error. The ISCD requires randomly selected patients or volunteers to be measured three times for 15 people or twice for 30 people to check precision. During re-measurement, the patient must descend from the examination table and then return to readjust their posture [9]. In addition, the ISCD requires that a 95% confidence interval be applied when calculating LSC.

When observing changes in bone density during follow-up tests, it is important to distinguish whether the measured values reflect changes in bone density in the body or measurement errors. It can be defined as a significant change only when it exceeds the LSC value. When applying the 95% confidence interval, the LSC value is calculated by multiplying the precision error value by 2.77 [10].

The LSC, using the CV% value recommended by ISCD, is 5.3% for the lumbar spine and 5.0% for the total hip. The bone density equipment showed a lumbar spine reading of 2.47% and a total hip reading of 1.61%. LSC using RMS-SD was 0.031 g/㎠ for the lumbar spine and total hip. In the ISCD of the total hip, the recommended CV% value was 6.9%. However, the CV% value for the femur neck was not calculated due to a mistake by the examiner. Nonetheless, the CV% value of the bone density meter and the LSC value using RMS-SD were confirmed to be very stable. It can help you diagnose the exact bone density follow-up diagnosis.

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