Journal of Clinical Densitometry: Assessment & Management of Musculoskeletal Health, vol. ■, no. ■, 1–4, 2015

1094-6950/■:1–4/$36.00
http://dx.doi.org/10.1016/j.jocd.2015.05.071

Original Article

Effect of Clothing on Measurement of Bone Mineral Density

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Abstract

It is unknown whether allowing patients to have BMD (bone mineral density) studies acquired while wearing radiolucent clothing adlib contributes appreciably to the measurement error seen. To examine this question, a spine phantom was scanned 30 times without any clothing, while draped with a gown, and while draped with heavy winter clothing. The effect on mean BMD and on SD (standard deviation) was assessed. The effect of clothing on mean or SD of the area was not significant. The effect of clothing on mean and SD for BMD was small but significant and was around 1.6% for the mean. However, the effect on BMD precision was much more clinically important. Without clothing the spine phantom had an least significant change of 0.0077 gm/cm^2, while when introducing variability of clothing the least significant change rose as high as 0.0305 gm/cm^2. We conclude that, adding clothing to the spine phantom had a small but statistically significant effect on the mean BMD and on variance of the measurement. It is unlikely that the effect on mean BMD has any clinical significance, but the effect on the reproducibility (precision) of the result is likely clinically significant.

Key Words: Accuracy; bone mineral density; clothing; precision; radiolucent.

Introduction

The significance of changes in BMD (bone mineral density) over time depends on calculation of LSC (least significant change), which is calculated based on variance of repeated measurements at each center *(1,2)*. ISCD (International Society of Clinical Densitometry) has advocated attention to many details to reduce variance between BMD measurements. However, even with attention to all of these details, there is still substantial measurement error, and efforts to control for other variables might further reduce the amount of measurement error and lower the LSC. We noted that, if we use a ceiling lift to move a disabled patient onto the densitometer, leaving the sling behind the patient while performing bone densitometry can introduce a small amount of measurement error although the sling is radiolucent *(3)*. We, therefore, wondered if allowing patients to dress adlib could introduce additional error into measurements of BMD. We sought to measure the contribution of variability of radiolucent clothing on the mean and variance of BMD measurements.

Received 05/19/15; Accepted 05/27/15.
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Methods

All measurements were performed on a Horizon A densitometer from Hologic (Waltham, MA), using the quality control spine phantom provided by the manufacturer. Spine scans were acquired in the fast array mode with repositioning between scans with the phantom alone (phantom A and phantom B) (Fig. 1), or with a gown in 2 layers over the phantom (gowned), or with heavy winter clothing over the phantom (clothed). The set of winter clothing used included the following:

(1) Underpants from Baby Gap (India), 100% cotton.
(2) Pair of tights from H + M (South Korea), 62% cotton, 35% polyester, 3% spandex.
(3) Light dress from H + M (Bangladesh), 56% cotton, 42% polyester, 2% elastane.
(4) Sweat pants from the Gap, 100% cotton.

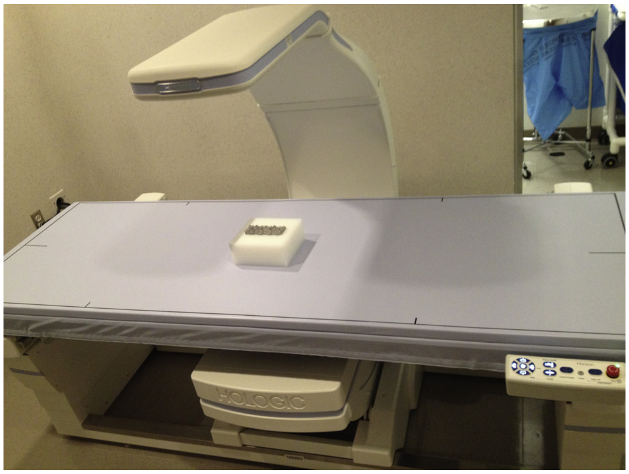

Fig. 1. The spine phantom without any clothing is depicted being scanned.

The scans were acquired in the following sequence: phantom alone (phantom A), phantom alone again (phantom B), gowned phantom (gowned), clothed phantom (clothed); the sequence was repeated 30 times.

The initial scan was analyzed in the analysis mode, and subsequent scans were analyzed using the compare mode to compare it to the appropriate baseline. However, there were 2 different ways to compare the scans:

(1) Compared to baseline of each group: in each group (phantom A, phantom B, gowned, and clothed), the first scan was analyzed using analysis mode, and each subsequent scan was compared with the first scan of the group. For example, the first gowned-phantom scan (gowned 1) was analyzed using the analysis option, and all subsequent gowned-phantom scans were compared with gowned 1.
(2) Compared to the most recent phantom A: gowned 5 was compared not with gowned 1 but rather with phantom A 5. This method was thought to more faithfully reproduce the situation in real life, where a patient would come in during the summer with light clothing, and then the next time would come in the winter with heavier clothing, and the heavy clothing scan would be analyzed by comparing to the light-clothing scan.

Statistics

Mean ± SD (standard deviation) was calculated using a spreadsheet in Excel from Microsoft (Seattle, WA). The significance of the differences in mean area, bone mineral content (BMC), and BMD between different groups was assessed using nonparametric tests because the data were not consistently normally distributed. Wilcoxon signed rank test was used for unpaired data and the Wilcoxon rank sum test for paired data; when multiple comparisons were done the significance was adjusted using the Bonferroni correction. The significance of differences in SD of area, BMC, and BMD between groups was assessed using the F test.

When we want to know the LSC when the scans are all done under the same circumstance (LSC_{same}), LSC is computed by taking the 30 measurements under that circumstance, computing the SD, and multiplying by 2.77. For instance, if we were interested in the LSC_{same} with clothing, the phantom was clothed, scanned, and repositioned 30 times, and the SD of the 30 measurements was multiplied by 2.77 to yield the LSC. When we want to know the LSC when the scans differ in clothing ($LSC_{different}$), LSC is computed by taking the SD of 30 paired BMD measurements, where the phantom is scanned once without clothing and once with clothing, calculating the RMS (root mean square) and multiplying by 2.77 *(1,2)*. The $LSC_{different}$ is calculated to give a sense for how much higher the LSC is when the amount of clothing varies between members of each pair of scans.

Results

When each scan was compared with the first in its group, the effects of clothing on mean and SD were small. When each scan was compared with the corresponding phantom A scan, the effects were more substantial.

When each scan was analyzed by comparing to the first in its group, neither the mean nor SD for the area differed among groups (Tables 1 and 2). The mean and SD for the BMC and BMD were slightly higher with more clothing, with gowned phantom higher than phantom alone and clothed phantom higher than gowned phantom. The differences for BMC between groups achieved statistical significance for the mean and SD only in the comparison between clothed phantom and the others, whereas for BMD, the difference in means achieved statistical significance for all groups but for the SD only when comparing phantom alone to the other groups. The mean BMD for the clothed phantom was 0.53% higher than the phantom alone.

When each scan was analyzed comparing to the corresponding phantom-alone scan which we think is the more valid analysis, neither the mean nor SD for the area differed among groups (Tables 1 and 2). The mean for the BMC and BMD were lower and SD higher with more clothing, but the differences with this analysis were less marked with the gowned phantom and more marked with the clothed phantom. The differences for BMC and BMD between groups achieved statistical significance for the mean and SD only in the comparison between clothed phantom and the others. The mean BMD for the clothed phantom was about 1.6% lower than the others.

The LSCs can be calculated in different ways to reflect the variance under different circumstances. First, we wanted to measure the variability when BMD is measured under one circumstance, and then again under that same circumstance after repositioning ($LSC_{same,}$ see Methods). For example, LSC_{same} is when the phantom is scanned with clothing and then scanned again with clothing after repositioning. This calculation of the LSC_{same} for phantom alone, gowned