Technical Aspects of Dual Photon Absorptiometry of the Spine

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Bone mineral content measurement using dual photon absorptiometry has reached widespread clinical use. Of significant concern is the identification of artifacts and their influence on bone mineral content measurements. We observed artifacts due to disease processes within the body or substances that were injected, ingested, or otherwise introduced into the body.

Dual photon absorptiometry (DPA) is a method of measuring mineral content of bone using absorptiometry with a dual energy source, which makes it possible to correct for soft tissue and body fat. This is an essential feature in studying the lumbar spine (*1*).

Some aspects of performing DPA are not generally encountered in other nuclear medicine procedures. Reproducibility (high precision) and absolute measurement (accuracy) are required to follow patients over a long period to observe changes in bone mineral content (BMC) (*2*). Even in severe cases, individuals may only demonstrate a loss of mineral content of 7%–9% per year (*3,4*).

Without a thorough knowledge of the technical considerations that may influence the measurements, test results may be inaccurate. The most obvious of all technical aspects is quality control (QC). We undertook a study to evaluate standards that measure reproducibility in daily QC, evaluate variations with soft tissue thickness, and measure variations caused by distance changes from the imaging table to the spine.

MATERIALS AND METHODS

The DPA system* used has a 4 × 4 mm pixel size. Our DPA unit is in close proximity to an imaging camera dedicated to gated blood pool imaging, and approximately ⅛ in. of external lead shielding was added to the detector to eliminate occurrence of a variable background. Background checks have been made, purposely planting 20 mCi of technetium-99m (^{99m}Tc) at 14 feet, and no significant contribution by the technetium gamma rays has been detected.

Two types of standard are used to monitor the accuracy and performance of the imaging system. A primary three-step standard is used when significant drift or change is noted, or other major changes such as source replacement occur. The three-step standard contains three concentrations of a mineral equivalent solution, which mimics hydroxyapatite crystals in bone. The secondary standard was an aluminum rod and is used in daily qualitv control.

Differences in patient body thickness were studied by varying the depth of water used in daily QC in 2-cm increments from 12–24 cm and scanning the aluminum rod at each depth. To evaluate the effect of distance from the spine to the scanning table, the primary standard was placed in 16 cm of water at various heights above the scanning table, and measurements were obtained.

Finally, we reviewed the results of 600 cases to identify the causes of artifacts seen in DPA studies.

RESULTS AND DISCUSSION

The analysis of data collected from daily QC revealed a reproducibility of 1.5% with the primary standard and 1% SD with the aluminum rod. This is well within the performance limits of the instrumentation as provided by the manufacturer.

In the phantom study, no significant variation due to patient thickness was encountered until a depth of 24 cm was reached (Table 1). The primary standard was also scanned using identical depth variations, and again no significant variation was noted (Table 2).

The effects of phantom measurements to study spine-to-table distance effects are found in Table 3. Bone mineral content measurements decreased with increasing distance between the spine and table; however, these measurements did not exceed normal variation limits (Table 3). We also asked other laboratories using the same system to scan the aluminum rod; differences of approximately 1% were found.

TABLE 1. Simulations of Variations in Patient Body Thickness Using the Secondary Standard

Depth of water (cm)	Secondary standard (gHA/cm)*
12	2.82
16	2.85
18	2.83
21	2.80
24	2.87

*gHA/cm, grams hydroxyapatite per centimeter.

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TABLE 2. Simulations of Variations in Patient Body Thickness Using the Primary Standard

Depth of water (cm)	Primary standard (gHA/cm)* (2nd step fit)
12	2.88
16	2.94
18	2.85
21	2.92
24	2.91

*gHA/cm, grams hydroxyapatite per centimeter.

TABLE 3. Simulations of Variations in Distance from Scanning Table to Spine

Elevation (cm) of primary standard in water	Primary standard (gHA/cm)* (2nd step fit)
0	2.84
2	2.82
4	2.79
7	2.75

*gHA/cm, grams hydroxyapatite per centimeter.

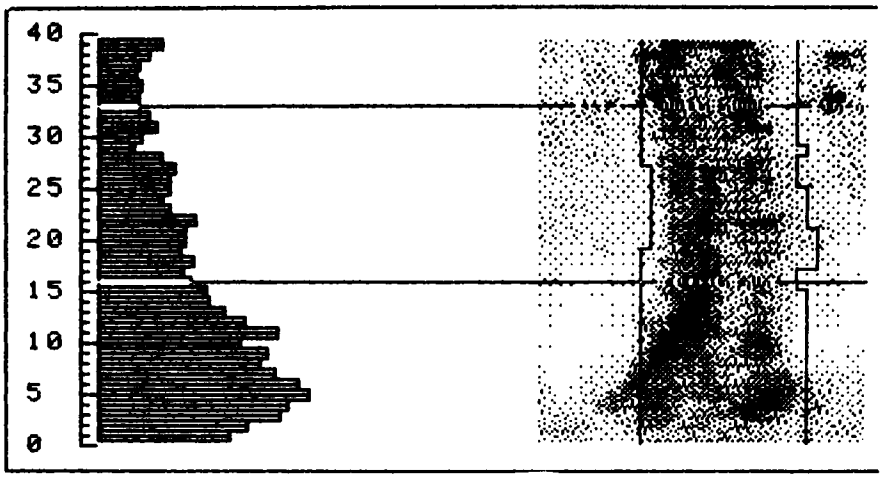


FIG. 1. Artifacts due to two disease processes—calcified lung granuloma (top right) and osteoarthritis (bottom center).

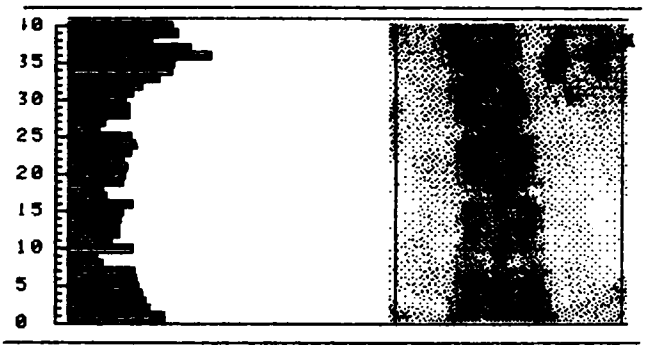


FIG. 2. DPA of 66-yr-old female with hyperparathyroidism. Arrows indicate presence of renal stones.

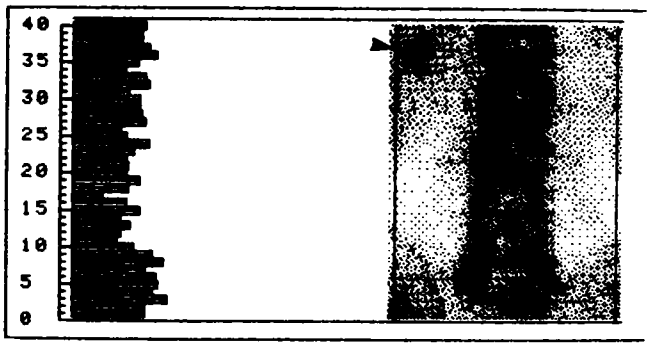


FIG. 3. DPA of 71-yr-old female with gallstones (arrows).

In 600 studies, several artifacts have been observed that were due to disease processes within the body or due to substances injected, ingested, or otherwise introduced into the body. Disease processes include osteophytes (Fig. 1), pancreatic or aortic calcifications, renal stones (Fig. 2), and gallstones (Fig. 3). Foreign substances seen have included contrast materials such as barium (Fig. 4), Lipiodol (Fig. 5), and Renografin (Fig. 6).

The artifact noted on the study of a normal patient (Fig. 7) intrigued us to investigate its origin, since it contributed significantly to the total BMC. We discovered this study was performed approximately 2 hr after oral ingestion of a 500-mg calcium tablet. The patient reported having had a lower intestinal tract disturbance the day of the test, which may have caused malabsorption of the calcium pill later recovered from a stool sample. A recent article (*5*) reported almost no absorption of oral calcium in the presence of low stomach acidity. The article also states this is especially true when oral doses

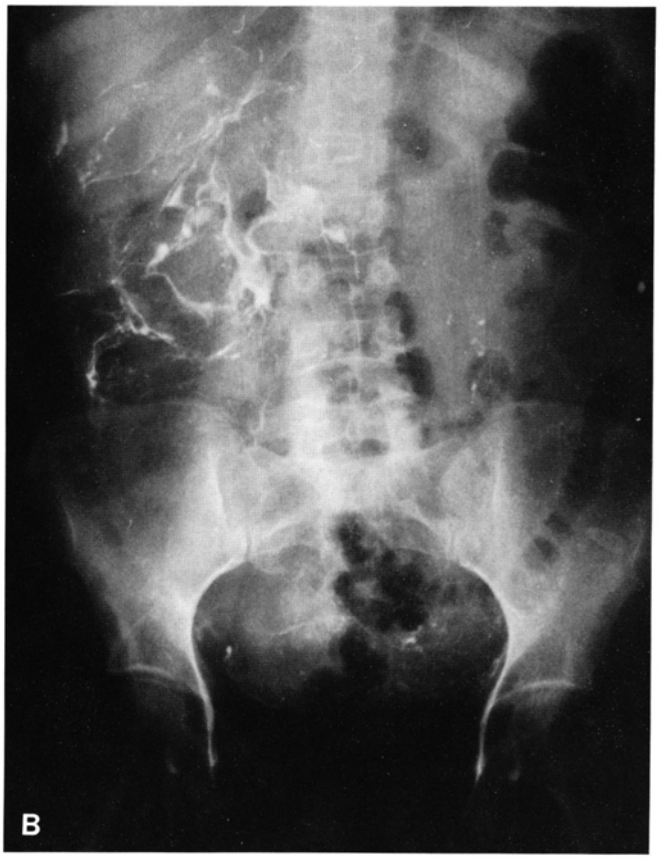
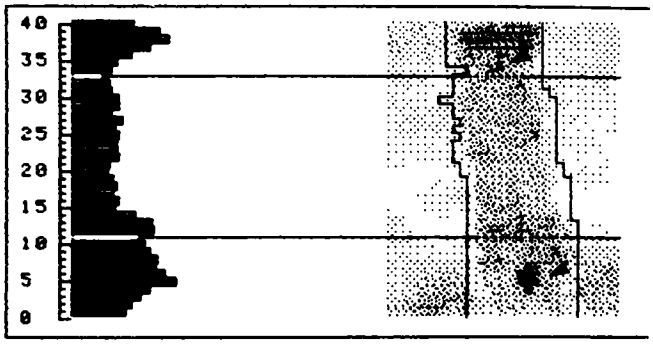


FIG. 4. A, DPA of 39-yr-old female, exhibiting free barium in peritoneal cavity; B, corresponding radiograph of the patient.



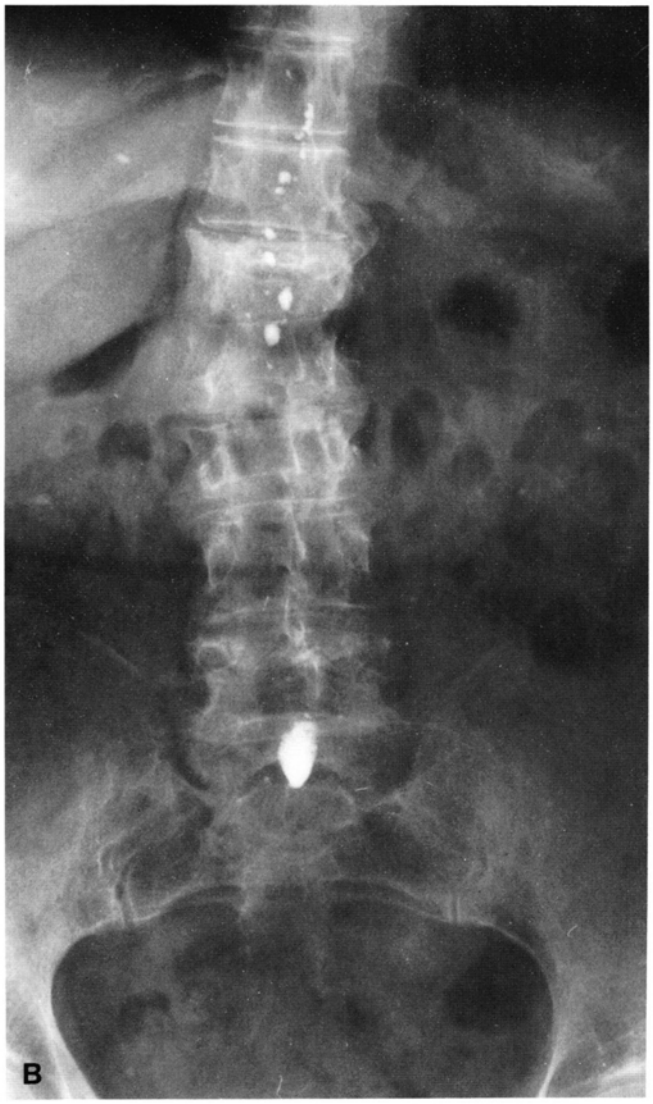


FIG. 5. A, DPA of 76-yr-old female performed after a myelogram in which Lipiodol had been used (arrows); B, corresponding radiograph of the patient.

of calcium are taken in the early morning and not in conjunction with a meal. A repeat study was performed 4 days later, with no evidence of this artifact. We have observed similar findings in two other patients.

As a result of these studies, scans of our primary standard and of a calcium tablet were performed (Fig. 8). A region-of-interest (ROI) was drawn around the tablet and the calculated mineral content was equivalent to 2.44 g of hydroxyapatite per square centimeter. Calcium tablets produced by other pharmaceutical companies were scanned and their calculated equivalencies are presented in Figures 9 and 10.

Recognition and identification, if possible, of any extraneous contribution to the total BMC is extremely important. If an artifact cannot be excluded from the ROI or if it is uncertain whether there is possible undetectable overlap of the spine itself, it may be necessary to repeat the study at a later date.

No significant variation was noted as a function of patient thickness, up to but not including 24 cm. Variation was noted with increase in distance from spine to scanning table but the

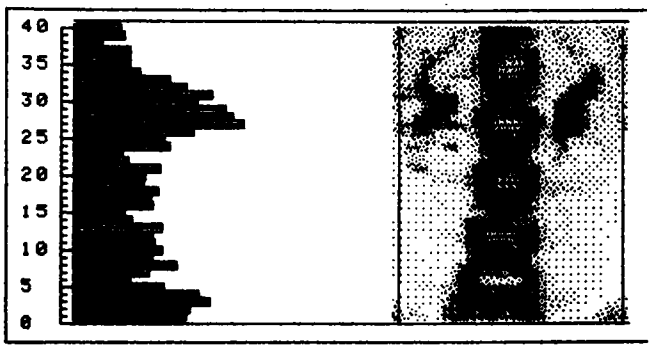


FIG. 6. DPA of 18-yr-old female performed 6 hr after an intravenous pyelogram in which Renografin had been used.

variation was within normal limits. This variation, however, was noted only for spine-to-table distances that exceeded normal deviations.

Artifacts are possible as a result of abnormal internal calcifications, previous use of contrast materials, and ingestion of calcium pills. Awareness of the possibility of artifacts, and recognizing them, is necessary in the performance of BMC measurements. If artifacts are present, the study may be repeated at a later date. An understanding of the limitations and use of careful techniques are necessary in performing bone mineral studies.

NOTE

*Model BMC Lab 22A, Novo Diagnostic Systems, Wilton, CT.

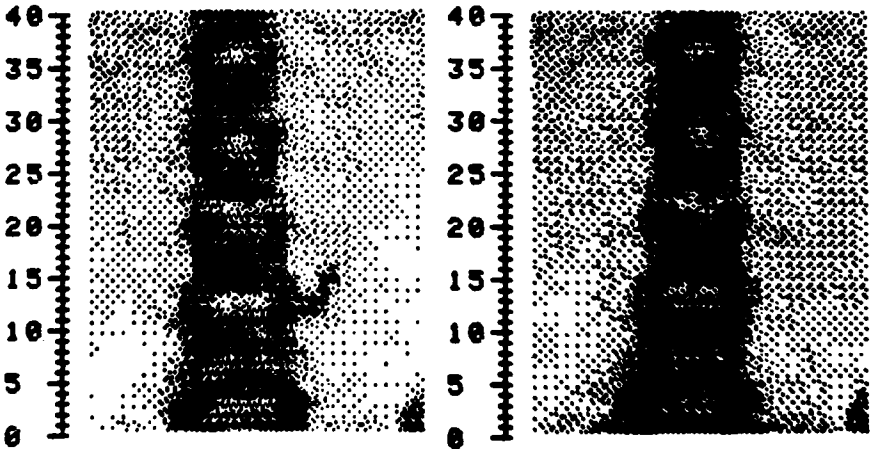


FIG. 7. DPA revealing incomplete digestion of orally administered calcium tablet (left) and an artifact-free repeat study 4 days later (right).

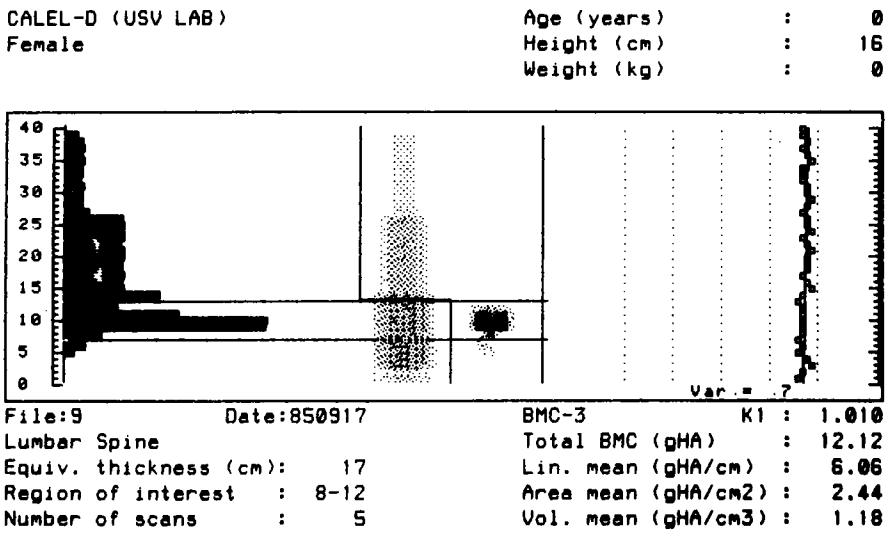


FIG. 8. Scan of primary standard and a calcium tablet (Calcel-D, manufactured by USV Laboratories).

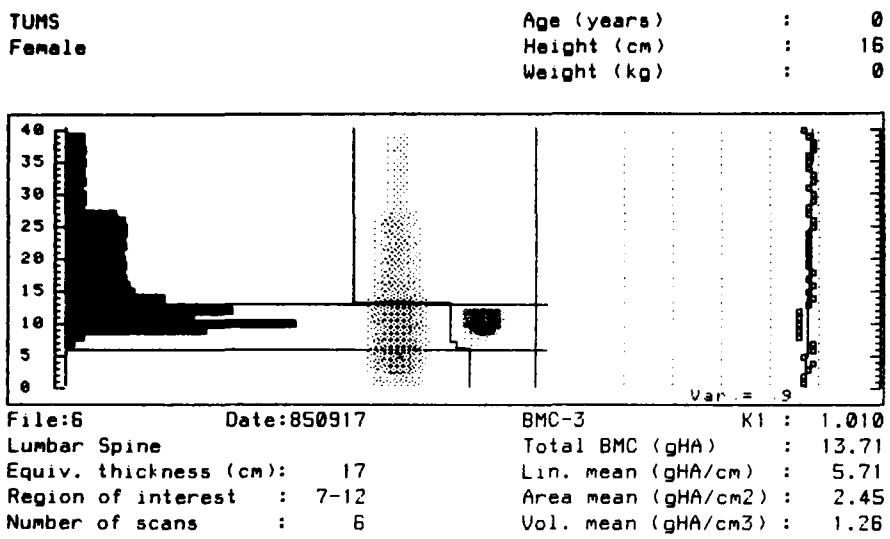


FIG. 9. Scan of primary standard and a nationally advertised antacid containing calcium.

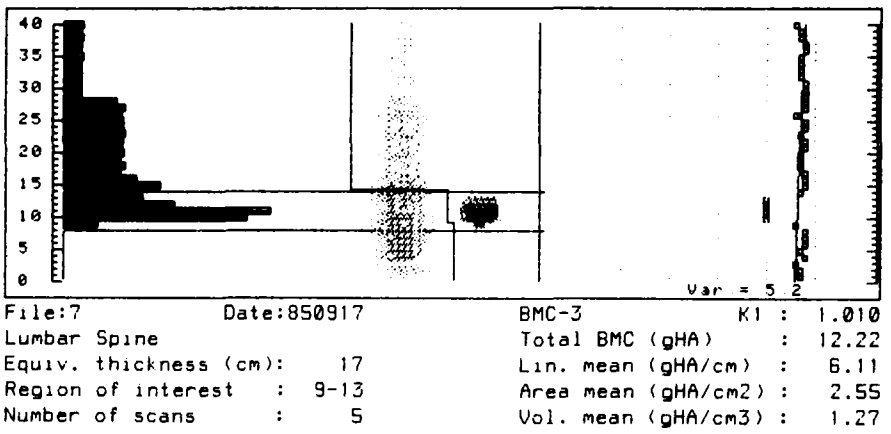


FIG. 10. Scan of primary standard and another nationally advertised antacid.

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