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# Artifacts and Incidental Findings Encountered on Dual-Energy X-Ray Absorptiometry: Atlas and Analysis

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**Bone mineral densitometry (BMD) using dual-energy x-ray absorptiometry (DEXA) has been widely adopted as the standard method of assessing bone density. Although not intended to be a primary imaging modality, the technique generates attenuation map images that are used to guide region-of-interest placement. Artifacts and incidental findings are frequently encountered on the DEXA images, some of which directly affect BMD values and others that are only of incidental importance to clinical practice. We systematically review a variety of artifacts and incidental findings that may be encountered on DEXA, illustrated by a collection of findings from our own practice. Being cognizant of these unexpected abnormalities, and understanding their etiology, will prepare the reader to more readily appreciate significance of these findings when seen in clinical practice.**
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## Introduction

Dual-energy x-ray absorptiometry (DEXA) leverages the differential attenuation of photons of disparate energies to determine an areal bone mineral density (BMD).[1] Although there are differing designs of DEXA scanners, they all serve to produce attenuation maps of the regions studied, typically comprising the lumbar spine and hip and occasionally including the forearm as well. By applying semiautomated regions-of-interest (ROIs) to the BMD map, an areal average density for each ROI is obtained and compared with population norms, yielding *T* and *Z* scores. As a rule, the state of bone mineralization is reflected by the *T* and *Z* scores, whereas the rate of change of mineralization is indicated by variation in areal BMD measurements over time.

Although DEXA images are of lower resolution than plain film radiography, they serve several important functions. As noted by Jacobson et al,[2] DEXA images are used by technologist and physician to (1) confirm adequate positioning and appropriate placement of ROIs; (2) detect patient motion during the study; (3) identify overlying hardware, calcification, or other dense objects that might alter BMD; and finally (4) detect other disease conditions that, though not affecting BMD measurements, are themselves of clinical importance. Indeed, artifacts are frequently observed in the assessment of BMD using DEXA. It has been reported that approximately one-third of patients have findings on lumbar spine DEXA imaging, which lead to the exclusion of at least one vertebral level.[3] Owing to the high prevalence of artifacts, clinicians should be aware of the gamut of artifactual findings to properly interpret the studies. For example, BMD derived from a region with artifactually elevated or diminished BMD should be discounted as a reliable measure of bone mass for the purpose of predicting fracture risk. In the spine, this may entail excluding individual vertebral bodies from analysis, and more extensive involvement will require abandoning the lumbar spine altogether. BMD derived from a hip region affected by artifact should likewise be discounted; the contralateral hip or forearm may be chosen as an alternate measurement site.[4]

In this article, we systematically review both artifacts that can lead to incorrect interpretation of DEXA studies and incidental findings that do not affect BMD but may have relevance to the patient's medical condition, all illustrated with examples from our own clinical experience. For categorization, we have

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subdivided osseous conditions into focal and diffuse, the latter category affecting the spine and hip alike in a relatively symmetric manner.

## Osseous Conditions With Focal Increase in BMD Measurements

The so-called "degenerative changes," more accurately described as osteoarthritic changes, are the most common source of artifact encountered on DEXA studies. Frequently seen in older patients, these changes manifest in the lumbar spine as end-plate osteophytosis, sclerosis, disk space narrowing, and facet joint arthropathy (Fig. 1A and B). On DEXA, boney proliferation and sclerotic change results in an increase in the measured BMD in excess of what would be measured in patients without such changes.[5-12] Even mild osteophytosis can increase lumbar spine BMD by 24%.[13] Although localized disease is relatively easy to detect, when multiple levels of the lumbar spine exhibit degenerative change in a relatively homogeneous manner, presence of osteoarthritic change may be paradoxically difficult to appreciate. In this case, elevated *T* and *Z* scores may suggest a sclerosing process, especially when there is a disparity between spine and hip or forearm, where DEXA ROIs are less prone to artifact from osteoarthritis.

DEXA measures an "areal density," which is a measure of mass per unit projected area. On frontal views typically used for DEXA, the component of attenuation owing to the load-bearing cancellous and cortical bone cannot be isolated from that owing to overlying boney proliferative changes of osteoarthritis, which do not contribute to load-bearing capability. The contribution of osteoarthritic changes to net BMD will result in the overestimation of effective bone mass within the affected regions and will therefore underestimate the fracture risk.[14-18] It has been suggested that lateral DEXA measurements of the lumbar spine would minimize the effect of degenerative changes[19-23]; however, current International Society for Clinical Densitometry guidelines do not support this variation in standard clinical practice.[4] Although osteoarthritic changes of the hip can also lead to inflated BMD values,[14,24,25] the femoral neck and radial distal-third region are only minimally affected by degenerative change, rendering these areas relatively spared by this artifact.

Diffuse idiopathic skeletal hyperostosis (DISH) is a spondyloarthropathy of the spine characterized by ossification of the anterior and posterior longitudinal ligaments and paraspinal connective tissues. These changes can lead to overestimation of lumbar BMD by 24%-39% as compared with quantitative CT, which assays only the unaffected "true" trabecular bone.[26-31] In spite of an increase in the apparent BMD, it has been suggested that fracture risk is actually increased in patients with DISH.[27] DEXA-derived BMD values have also been reported to be elevated in the hip[28] and distal radius in this condition.[29]

Ankylosing spondylitis is a chronic inflammatory disease with male predominance affecting the axial skeleton, which usually develops in early adulthood.[32] The radiological manifestations include sclerotic changes at the vertebral end plates, syndesmophytic ankylosis, as well as calcification of the interspinous ligaments. These lead to the classic radiological descriptions of the "shiny corner sign," "bamboo spine," and "dagger spine" (Fig. 1C), respectively, all of which can elevate BMD results.[33-36] Patients with ankylosing spondylitis commonly have osteoporosis of the axial and proximal appendicular skeleton,[35,37] likely secondary to local, chronic inflammation. It appears that BMD is actually reduced in early or mild disease[38,39] but can be increased in advanced, more

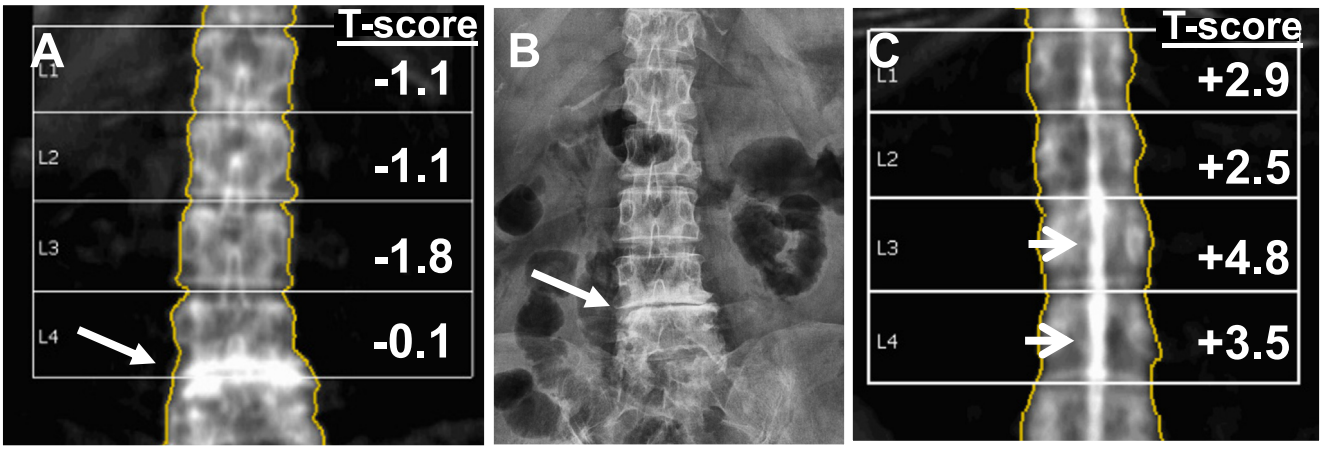



**Figure 1** Degenerative changes are an extremely common finding in patients undergoing DEXA. The patient in (A) shows severe end-plate sclerosis of the L4/L5 disc space (arrow) with a significantly increased BMD value at L4 compared with L1-L3. Individual lumbar body *T* score values have been listed on the image. Note the abrupt increase in *T* score at the L4 level. When L4 is omitted from the analysis, the resultant lumbar *T* score is −1.3 rather than the originally calculated value of −1.0. (B) Correlative radiograph illustrates severe disk disease with narrowing of the disk space, osteophyte formation, and adjacent sclerosis, all at the L4-L5 level (arrow). (C) In a different patient with ankylosing spondylitis, the classic finding of "dagger spine," caused by calcification of the interspinous ligament, is apparent (arrows). Elevated *T* scores are noted throughout the spine.

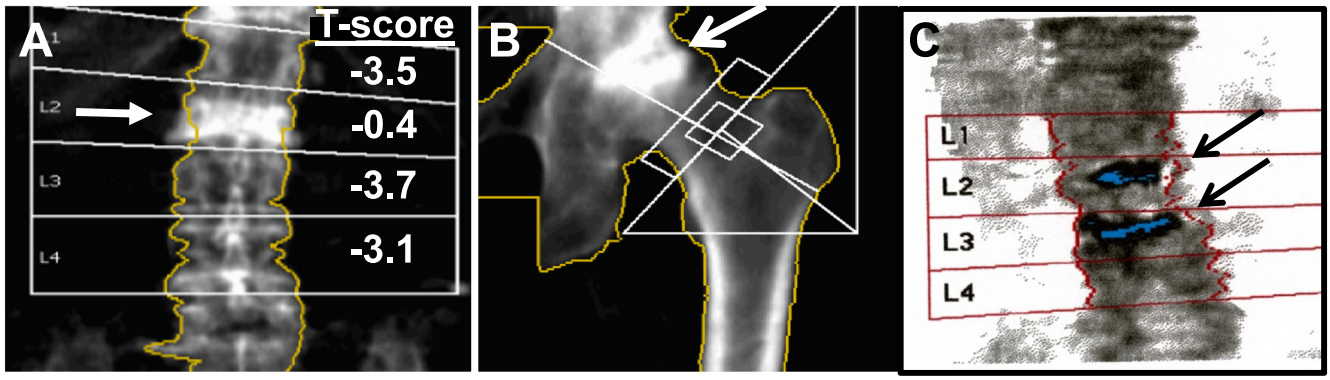



**Figure 2** (A) An 88-year-old woman with fracture of the L2 vertebral body (arrow) demonstrates diffusely decreased BMD with exception of the level of the compression fracture. (B) A patient with avascular necrosis of the left femoral head (arrow). The femoral head appears dense and is associated with flattening and deformity. (C) DEXA image in a patient status post vertebroplasty of L2 and L3 with introduction of radiopaque cement preparation (arrows).

chronic cases, likely owing to the proliferation of sclerotic change. Lumbar spine BMD results can therefore be misleading, particularly when acquired in frontal projection.[22] BMD measured in the distal appendicular skeleton appears unaffected by artifact[33,40,41]; it has been suggested that in this patient population, BMD measurement can most reliably be obtained from the femur.[34]

Insufficiency fractures of the spine are a common finding in patients undergoing DEXA[42] and have dual significance: (1) the presence of an insufficiency fracture is an important

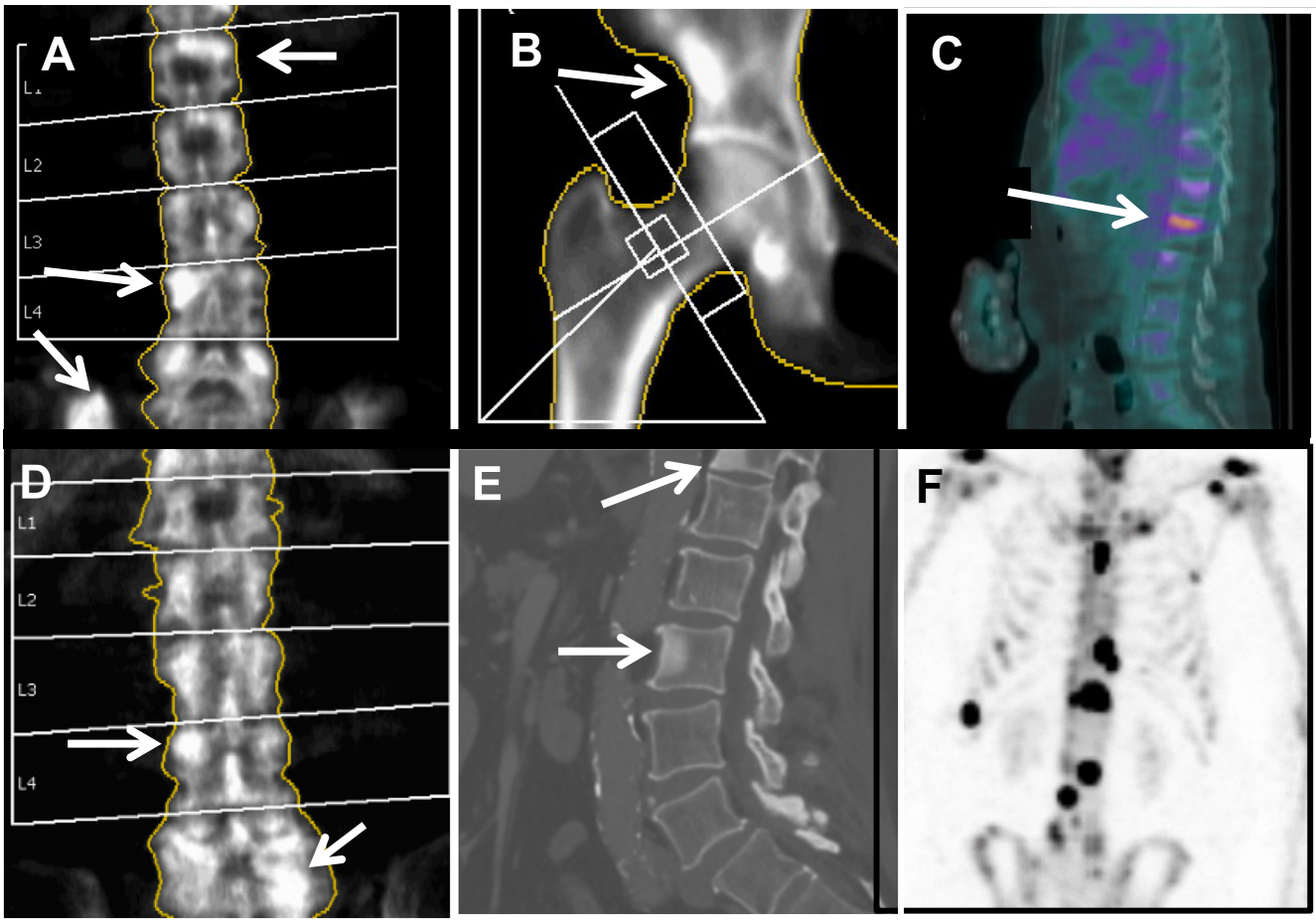



**Figure 3** Sclerotic metastases on DEXA (arrows). A 65-year-old woman, with known breast cancer (A-C), for evaluation of BMD before therapy. DEXA images of the spine (A) and hip (B) demonstrate sclerotic boney metastases, corroborated on representative sagittal FDG-PET/CT image (C). A 67-year-old man with Gleason 7 prostate cancer (D-F). Metastases to the spine are noted on DEXA (D), CT (E), and radionuclide bone scan (F).

independent factor in the overall fracture risk assessment and (2) fractured vertebral bodies should be omitted from the ROI as their presence will result in an artifactual increase in the reported BMD.[43] Fractures do not change the amount of calcification present within vertebrae; however, loss of height leads to a relative concentration of bone resulting in an absolute increase in the areal bone density. Vertebral fractures are easily recognized on DEXA images owing to the loss of vertebral body height coupled with a sclerotic appearance[2] (Fig. 2A). In a similar manner, condensation of the bone in avascular necrosis results in deformity and increased density (Fig. 2B). Treatment of vertebral fractures by vertebroplasty will also increase the measured BMD, owing to density of the polymethylmethacrylate cement preparation, which has purposefully been rendered radiopaque[44,45] (Fig. 2C). A study using single photon absorptiometry demonstrated that following wrist fracture, BMD of the forearm is initially decreased but ultimately becomes persistently increased by 10 years after fracture.[46]

Sclerotic osseous metastases, not uncommon in the age group being studied by DEXA, can cause increased BMD; prostate cancer in men and breast cancer in women represent the most frequent etiologies in this age group[47] (Fig. 3). It is important to maintain a high suspicion for boney metastases, as DEXA may be first examination to detect abnormality.

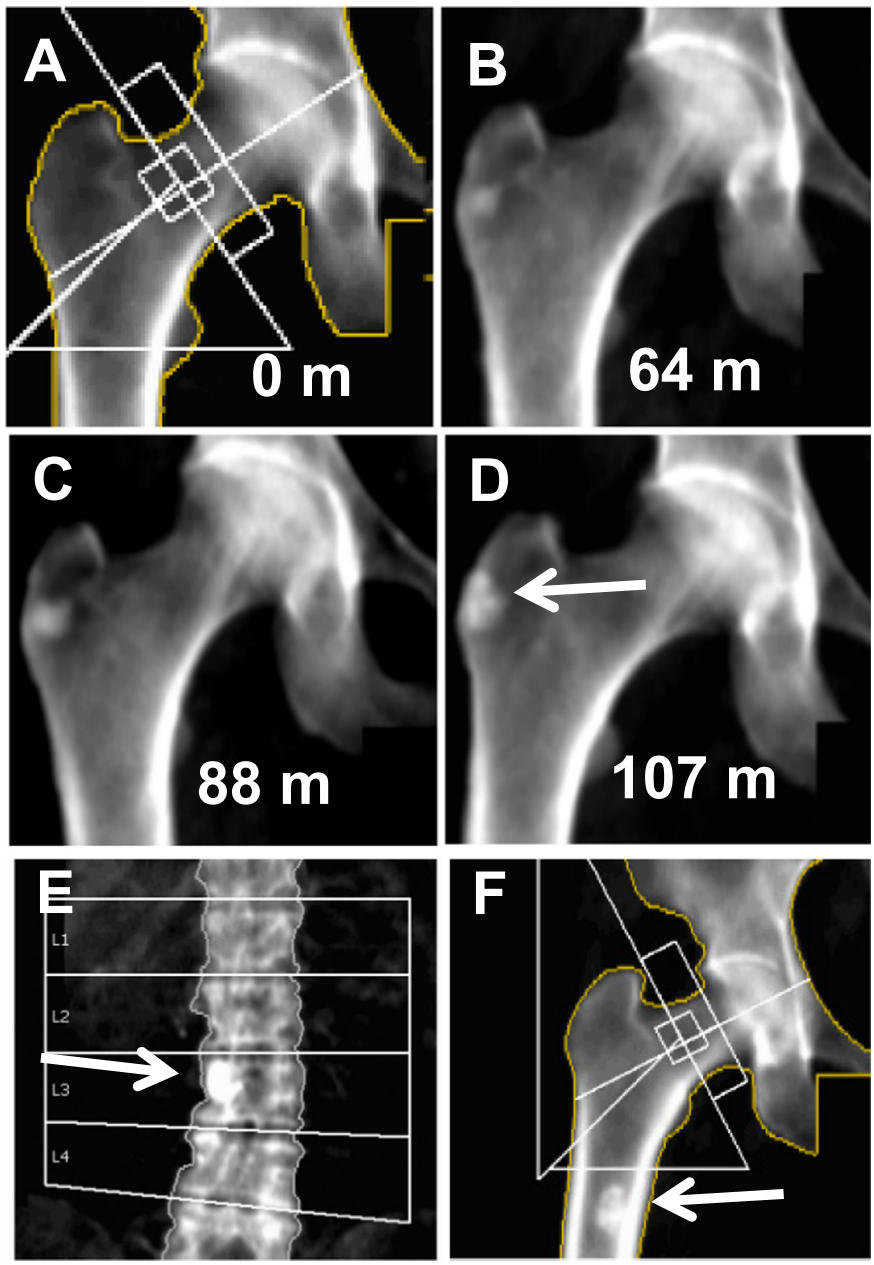



**Figure 4** Benign bone lesions. (A-D) A 71-year-old woman with slowly growing enostosis at the base of the greater trochanter within the "total hip" ROI (arrow), slowly growing over the span of 9 years. Interval (in months) between image A and subsequent studies is indicated. (E) Enostosis located in the L3 pedicle (arrow). This vertebral body level should be excluded from the lumbar ROI. (F) Enchondroma incidentally detected in the proximal femoral shaft, below the right hip ROI (arrow).

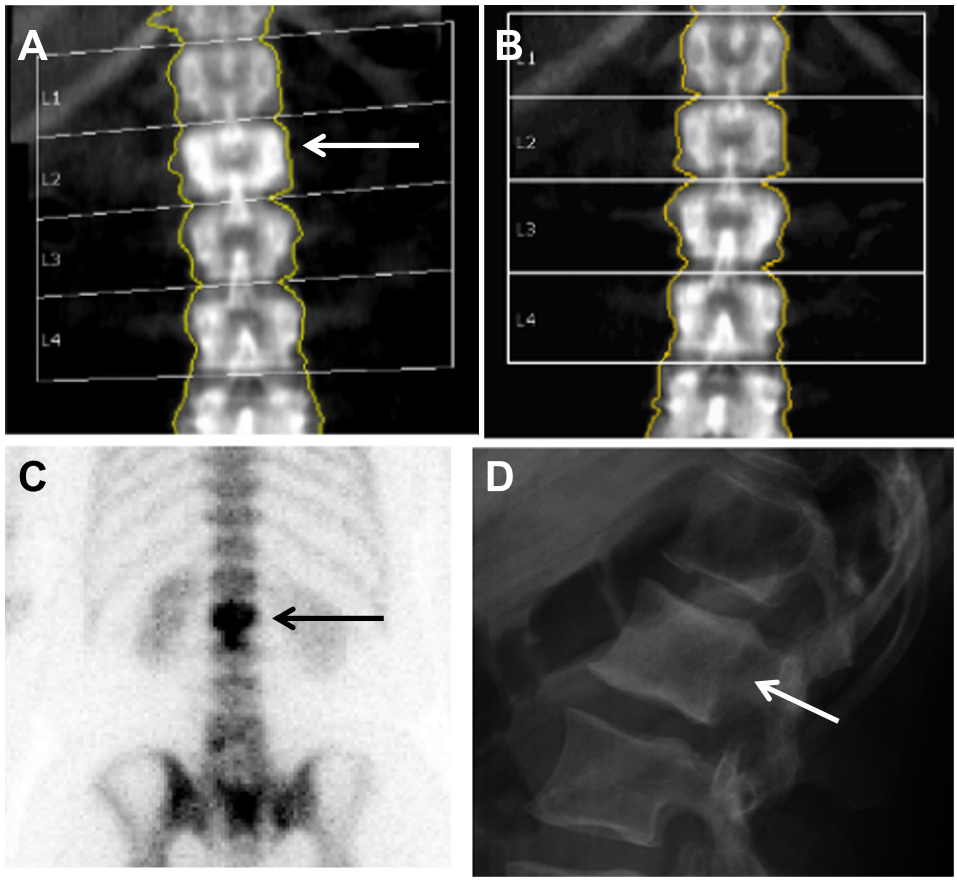



**Figure 5** A 50-year-old woman with a sclerotic L2 vertebral body, typical of Paget disease (arrow). Prior study from 5 years earlier (B) does not evidence these findings. Recent $^{99m}$Tc-MDP bone scan (C) and lateral view of the lumbar spine (D) confirm presence of a pagetoid vertebral body (arrows). MDP, methylene diphosphonate.

Benign bone neoplasms such as osteoblastoma and enostosis (Fig. 4) can also lead to focally increased bone density. Correlation with conventional imaging is required to further characterize osseous lesions as DEXA images are not optimized for this purpose.

Paget disease frequently involves sites imaged on DEXA including the spine, pelvis, and proximal femurs[48] and accounts for approximately 1.4% of incidentally found elevated BMD values.[49] Radiological findings include thickening of the cortical bone and coarsening of the trabeculae, which, on DEXA, will demonstrate diffuse sclerosis[50-52] (Fig. 5). In the spine, thickening of cortical bone can lead to the classic "picture frame sign." In the pelvis and hip, findings include thickening of the iliopectineal and ilioischial lines. Despite associated increase in BMD, fracture risk actually appears to be increased.[53,54]

## Osseous Conditions With Generalized Increase in BMD Measurements

Though rare, elevated BMD may be present diffusely throughout all bones. It has suggested that BMD *Z* scores above +2.5 should be "flagged" as abnormally elevated.[55] Gregson et al[56] have published a thorough review of causes of diffusely increased BMD, subdivided into acquired and inherited conditions, including an otherwise unexplained high-bone-mass phenotype. Because findings are not specific, clinical evaluation and correlative imaging must be consulted to arrive at a diagnosis.

The term renal osteodystrophy includes several disparate disorders of bone metabolism; however, all are characterized by some combination of abnormal mineralization, hormonal dysregulation, variations in microarchitecture, and extraskeletal calcification. The main subtypes of renal osteodystrophy include osteitis fibrosa cystica, adynamic bone disease, osteomalacia, and mixed uremic osteodystrophy.[57] Although many of these conditions are associated with decreased BMD, elevated values have been reported in patients with osteitis fibrosa cystica.[58] A classic rugger-jersey spine appearance is caused by sclerotic bands at the superior and inferior vertebral end plates.[59,60]

Skeletal fluorosis can result in diffusely elevated BMD, owing to dietary, environmental, and industrial exposure.[61-63] Approximately 50% of ingested fluoride

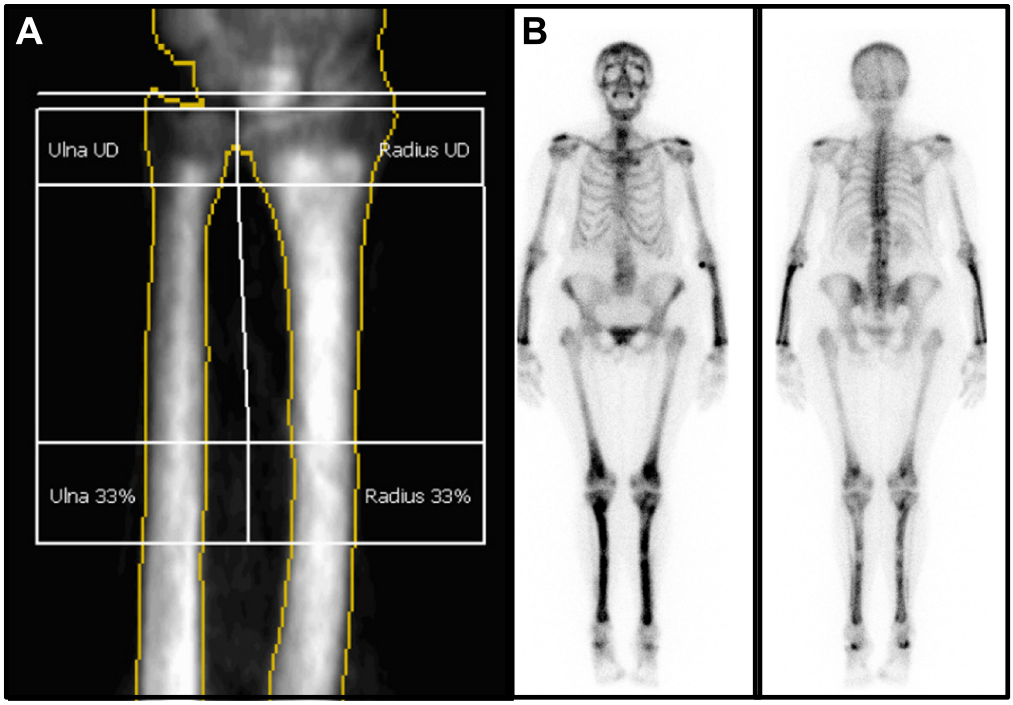
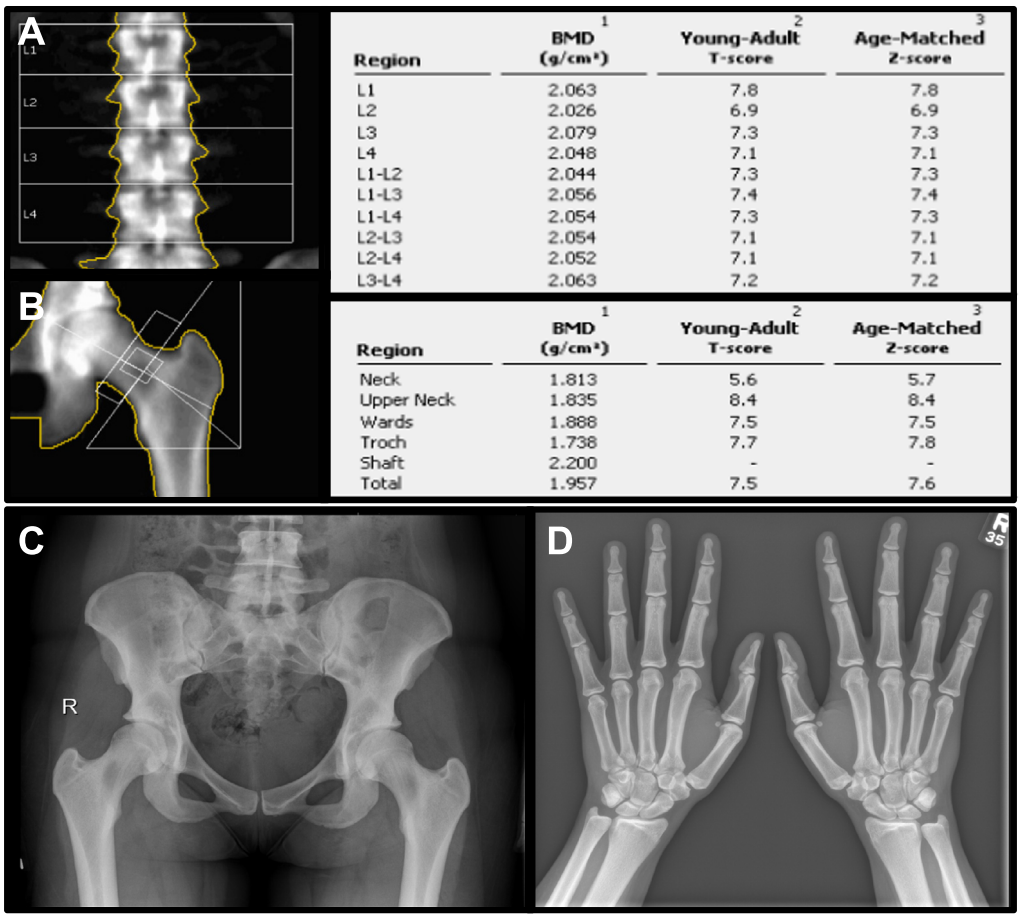



**Figure 6** Metabolic and genetic causes of diffusely increased BMD are distinctly uncommon and can be due to a host of different conditions. (A) Diffuse sclerotic changes within the trabecular bone of the distal forearm. Radionuclide bone scan (B) demonstrates symmetric, increased osteoblastic activity in multiple distal long bones. The patient is diagnosed with Camurati-Engelmann disease.




| Region | BMD (g/cm²) [1] | Young-Adult T-score [2] | Age-Matched Z-score [3] |
|---|---|---|---|
| L1 | 2.063 | 7.8 | 7.8 |
| L2 | 2.026 | 6.9 | 6.9 |
| L3 | 2.079 | 7.3 | 7.3 |
| L4 | 2.048 | 7.1 | 7.1 |
| L1-L2 | 2.044 | 7.3 | 7.3 |
| L1-L3 | 2.056 | 7.4 | 7.4 |
| L1-L4 | 2.054 | 7.3 | 7.3 |
| L2-L3 | 2.054 | 7.1 | 7.1 |
| L2-L4 | 2.052 | 7.1 | 7.1 |
| L3-L4 | 2.063 | 7.2 | 7.2 |

| Region | BMD (g/cm²) [1] | Young-Adult T-score [2] | Age-Matched Z-score [3] |
|---|---|---|---|
| Neck | 1.813 | 5.6 | 5.7 |
| Upper Neck | 1.835 | 8.4 | 8.4 |
| Wards | 1.888 | 7.5 | 7.5 |
| Troch | 1.738 | 7.7 | 7.8 |
| Shaft | 2.200 | - | - |
| Total | 1.957 | 7.5 | 7.6 |

**Figure 7** A female patient in her third decade demonstrates markedly increased BMD in the spine (A) and hip (B), with *Z* scores in the 7-8 range. Review of the patient's imaging (C and D) and medical history resulted in a diagnosis of Albers-Schonberg disease (osteopetrosis, autosomal dominant type 2).

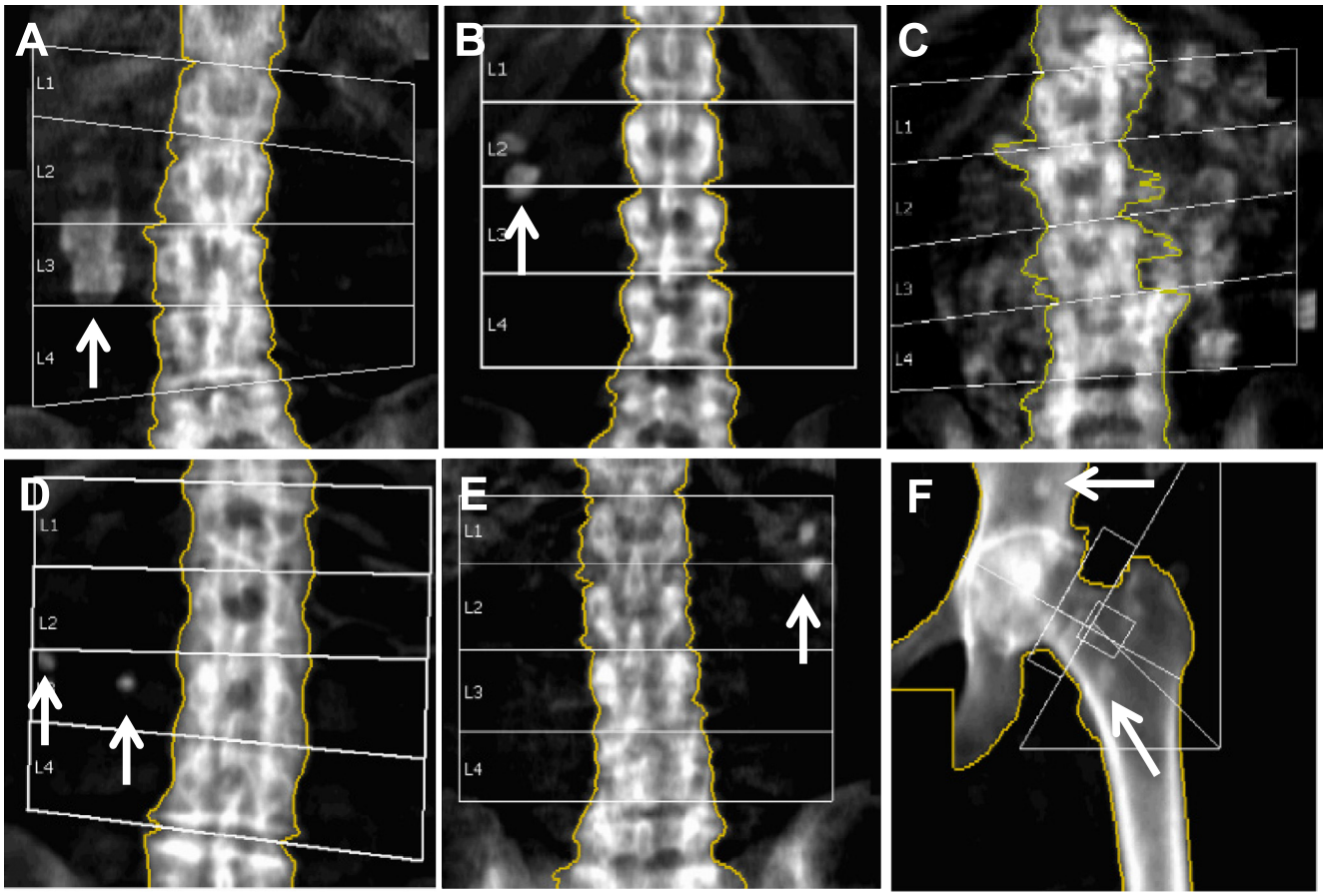



**Figure 8** Illustration of six examples of calcification on DEXA imaging (arrows). (A) Porcelain gall bladder, (B) gallstones, (C) huge leiomyofibroma with extensive calcifications overlapping lumbar spine, (D) calcified retroperitoneal lymph nodes, (E) left renal stones, and (F) buttock granulomata overlying hip ROIs.

localizes to the bones within 24 hours whereas the remainder undergoes renal clearance.[64] Retained fluoride associates with hydroxyapatite and is incorporated within the boney matrix, serving to increase osteoblastic activity.[65,66] Radiological features of fluorosis are variable but include calcification of the ligaments, tendons, muscles, and interosseous membranes, as well as osteosclerosis.[67-70] Although osteopenia and osteoporosis have also been reported in patients with fluorosis, more commonly, patients exhibit elevated lumbar BMD values.[71-73] Despite this increase in BMD, treatment of osteoporosis with sodium fluoride does not decrease vertebral fracture risk.[74,75]

Other rare causes of diffusely increased BMD include hereditable conditions such as Camurati-Engelmann disease (progressive diaphyseal dysplasia)[76,77] (Fig. 6), Albers-Schonberg disease (osteopetrosis, autosomal dominant type 2) [78] (Fig. 7), sclerosteosis,[79] van Buchem disease,[80] pycnodysostosis,[81] and Buschke-Ollendorff syndrome (osteopoikilosis).[82] Myeloproliferative disorders such as myelofibrosis[83] as well as infectious causes, such as hepatitis C–associated osteosclerosis,[84] can also diffusely elevate BMD. Acromegaly can result in diffusely increased BMD[85,86] whereas mastocytosis results in either diffuse osteopenia or sclerosis.[87,88] In many of these conditions, the patient's systemic disorders are apparent and already known at the time of bone density examination.

## Nonosseous Causes of Elevated BMD Measurements

Cholelithiasis, nephrolithiasis, and calcified leiomyofibroma are frequently seen on DEXA. Porcelain gallbladders are occasionally noted, as are mesenteric calcifications, phleboliths, and calcinosis cutis (Fig. 8). Heterotopic ossification of the hip has been described as causing an apparent increase in BMD.[89] These extraskeletal calcifications represent a common manifestation of several pathophysiological processes. When overlapping boney ROIs, these densities can directly elevate the apparent BMD.[90] It has been reported, based on cadaver studies,[91] that densities located lateral to the spine have the potential to also lower apparent vertebral BMD through a process of subtraction, most significant when scanning vertebral bodies with low BMD. It is likely that this artifact is vendor and software-version specific.

The effect of aortic calcifications on lumbar spine BMD is much discussed in the literature. Though not universal,[92] most authors report that vascular calcifications have

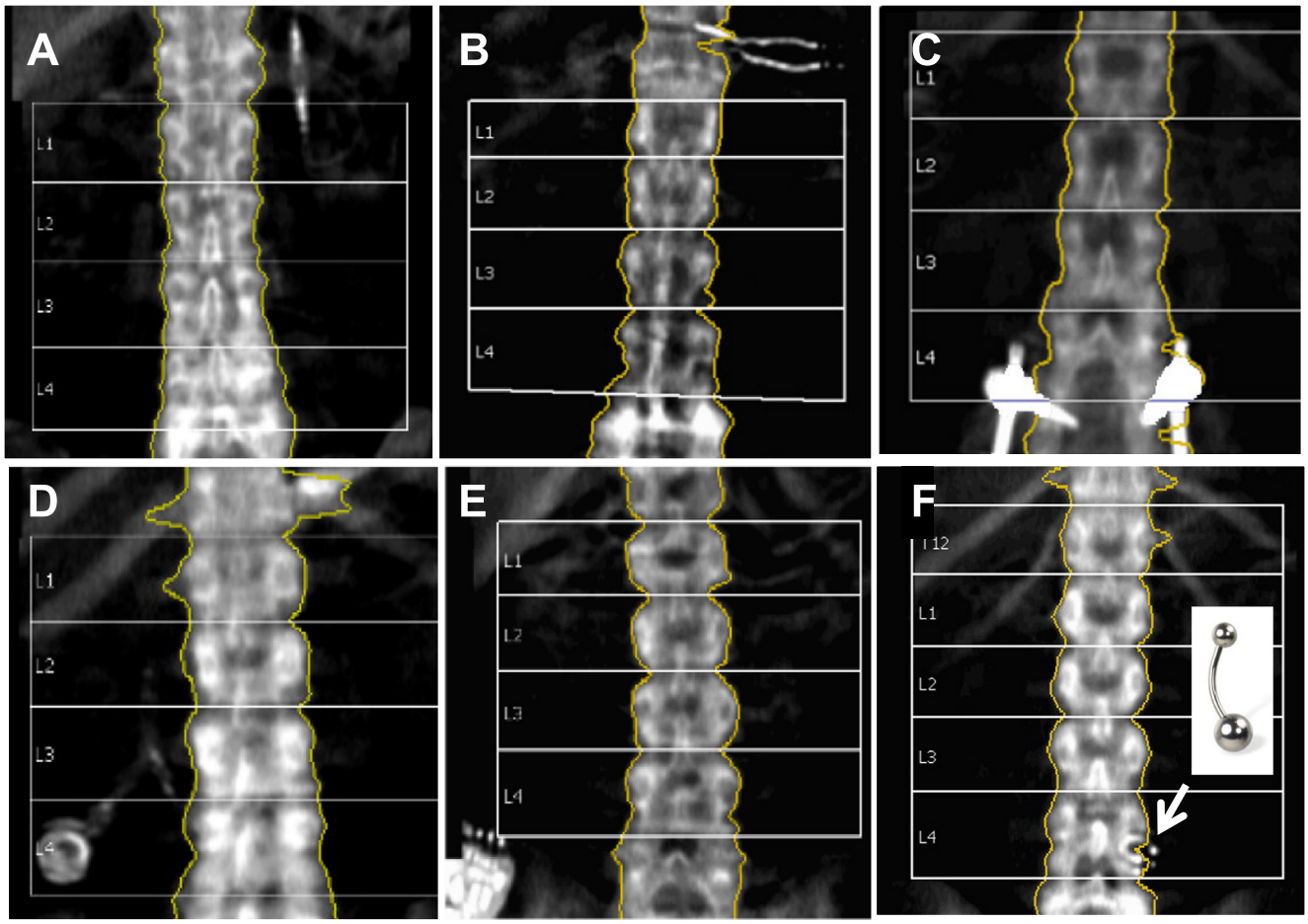



**Figure 9** Illustration of six examples of metallic hardware. (A) Ventriculo-peritoneal shunt connector (right upper corner), (B) ventricular pacemaker wire (right upper corner), (C) L4-L5 fusion hardware, (D) lap-band port (left lower corner), (E). sacral nerve stimulator (left lower corner), and (F) body piercing jewelry (see insert). In (C) and (F), the densities overlie the spine ROI, which necessitates editing to eliminate the offending artifacts.

no significant effect on BMD,[8,93,94] which is fortunate given the prevalence of atherosclerotic disease in the typical population studied.

In addition to calcified structures, metallic objects, located both within and outside of the patient, can be visualized on DEXA images including bra wires, body jewelry, spinal fusion hardware, and various other medical devices that have the potential to artifactually elevate BMD[95-97] (Fig. 9). Radiopaque medications, such as undigested calcium pills within the bowel, may overlie the lumbar spine.[98,99] Patients should also be screened for recent radiological procedures to avoid scanning individuals with retained bowel contrast, which has the potential to increase apparent BMD.[100,101]

It has been reported that the presence of dense metal overlying the lumbar spine can actually result in a "black hole artifact," which, dependent on the software used, may decrease the measured BMD value for the affected vertebral level.[102] It is theorized that the extreme densities encountered produce absorption far beyond the range typical of bone and tissue such that the difference between the low- and high-energy beams is unpredictable and without physical meaning.[102] Careful review of the DEXA images should help mitigate the effect of this artifact by excluding the affected vertebral level.

## Factors Leading to Decreased BMD Measurements

Systemic causes of diffusely decreased BMD are the usual subject of DEXA analysis and include postmenopausal changes, endocrine disorders, gastrointestinal disorders, marrow-related disease, rare genetic causes, chemotherapy and medication, and a variety of other miscellaneous conditions[103] often indistinguishable from each other on DEXA. In this discussion, we turn our attention to unusual and artifactual causes of decreased BMD.

Lytic bone lesions affecting single or multiple vertebral levels can reduce measured BMD values. These lesions are typically seen in multiple myeloma[104-108] and other lytic malignancies including breast cancer, renal cell carcinoma, melanoma, thyroid cancer, and hepatocellular carcinoma. Although the imaging findings on DEXA may be subtle, careful attention may reveal heterogeneity or focal lucency, suspicious for metastatic disease. Correlation with radiographs is warranted.

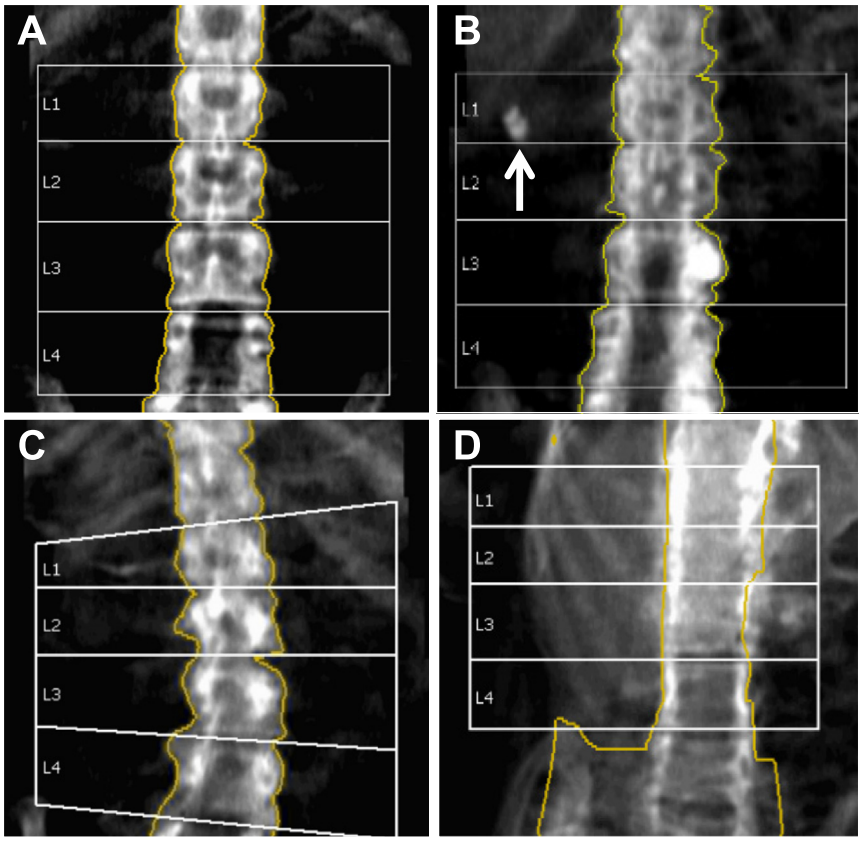



**Figure 10** Illustration of four conditions with defects of the posterior elements of the spine. (A) L4 laminectomy, (B) L3-L5 laminectomy and incidentally noted right renal calculus (arrow), (C) spina bifida involving L3-L5, and (D) spina bifida with extensive involvement of the entire spine. BMDs of the affected levels are markedly reduced and should not be used to assess fracture risk.

In addition to lytic bone metastases, Gaucher disease,[109,110] spinal hemangiomas, aneurysmal bone cysts, and fibrous dysplasia[111-113] are all potential causes of focally decreased BMD. A finding of focally decreased BMD should be reconciled with the patient's medical history, and correlative imaging as a new diagnosis of osseous metastases or other significant disorder is occasionally made on DEXA. As in the case of artifactually elevated BMD, regions affected by these processes should be omitted from analysis.

Laminectomy is a common surgical treatment of spinal stenosis. This procedure consists of surgical resection of the laminae and occasionally spinous process of the affected vertebral bodies. Treated patients will demonstrate decreased BMD owing to the lack of posterior elements[114] (Fig. 10A and B). Prior laminectomy is readily identified on DEXA images, and a history of spinal surgery should be evident on patient questionnaires.[115] Patients with spina bifida similarly will have decreased BMD values, owing to the congenital absence of posterior vertebral elements (Fig. 10C and D).

## Technical Factors Leading to Erroneous BMD Measurements

Multiple reports have been published regarding the effect of prior radionuclide administration on apparent BMD values.[116-118] It appears that the radionuclide photons down-scatter into the DEXA windows and decrease apparent attenuation, thereby resulting in falsely lowered BMD and fat content values.[116] Not all investigators have noted a significant effect[119]; it appears that the magnitude of reduction is related to system and technical factors.[120]

Proper patient positioning, a topic in its own right, is essential to obtain an accurate BMD measurement. Variation in positioning will lead to alteration (often increase) in measured hip BMD[121-125] and may also affect radius measurements.[126] Patients with scoliosis cannot lie with their spines straight on the table, which can make it difficult to properly delineate vertebral levels. DEXA images are typically used to assess proper positioning.[2]

Proper assignment of ROIs on DEXA images is also essential to obtain accurate BMD values. Variation in assigning the appropriate ROI can lead to erroneous BMD values in the spine, hip, and radius and bias serial measurements as well. In the spine, the types of error that most commonly occur include misidentification of vertebral end plates, miscategorization of opaque artifacts as bone, oversizing of ROIs, and mislabeling of vertebrae.[127] This latter error is likely related to the fact that 15% of the population has four or six lumbar vertebrae, with the last pair of ribs on T11 or L1.[128]

Another potential source of error is incorrectly assigning the race and sex of a patient undergoing DEXA,[129] which can

result in artifactually increased or decreased *Z* scores. We recently encountered a patient with an erroneous age on DEXA owing to propagation of an incorrect birth date from the hospital information system. Although the patient's age on hospital information system was known to be incorrect, it was linked to legal documents (themselves incorrect), which could not be simply corrected. So too, changes in assignment of patient sex, or of self-reported ethnicity, will change assigned *T* and *Z* scores.

Change in patient weight, as may be seen after bariatric surgery, may cause variation in perceived BMD. The Canadian Association of Radiologists has recommended that a 10% or greater change in weight over the period of monitoring should be noted as possibly leading to artifactual variation in BMD.[115] Indeed, Mann has demonstrated a change in apparent BMD following drainage of peritoneal dialysate fluid.[130]

## Conclusion

DEXA examinations are a frequently performed study used for screening and monitoring of bone health. Not infrequently, artifacts and incidental findings may be observed which warrant recognition by the interpreting physician.

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