Technical and patient-related sources of error and artifacts in bone mineral densitometry using dual-energy X-ray absorptiometry: A pictorial review

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Abstract

Dual-energy X-ray absorptiometry is currently the standard and validated tool for measurement of bone mineral density and for the evaluation of osteoporosis. Current densitometry scanners based on dual-energy X-ray absorptiometry method produce two X-ray beams with different energies to differentiate the overlapped soft tissue and bony structures, by creating two different attenuation profiles. Procedural guidelines are available to technicians and physicians to guarantee the best practice, including consistent positioning during scanning and standard reporting. However, similar to other imaging modalities, dual-energy X-ray absorptiometry may be influenced by technical errors, and thus, imaging artifacts may arise and accuracy and precision of the results may be influenced. This issue may, in turn, affect the final result and interpretation. Hence, the article is arranged with the intention of presenting some less common and rare technical and patient-related sources of error and resultant artifacts, from poor patient preparation to acquisition and data processing. Where appropriate, the corresponding tables of densitometric results (bone mineral density) and statistical parameters (T- and Z-scores) are provided.

Key words: Artifact, atlas, bone mineral densitometry, dual-energy X-ray absorptiometry

Introduction

The present article offers an illustrated compendium of technical and patient-related sources of error and resultant artifacts in dual-energy X-ray absorptiometry (DXA) with a potential impact on patient care in daily practice. In addition to images provided for recognition of artifacts, the pertinent results are also presented to offer the reader a head-to-head comparison as well as the effect of those artifacts on densitometric results. These factors with their potential impact are summarized and tabulated in Table 1.

Table 1: Summary of factors influencing the results of DXA scan with their potential impact and misdiagnosis

Source of error	Potential impact and misdiagnosis
Patient preparation and conditions/issues before scan	
Metallic objects in or attached to body/garments	High-density materials falsely increase BMD values due to higher radiation attenuation
Retained barium in bowels	Error in BMD measurement of lumbar spine if overlapped on the vertebrae
Ankylosing spondylitis	Erroneous measurement of BMD of the spine if significant calcification and sclerosis of perispinal ligaments and soft tissue are present Difficulty in labeling of vertebrae in severe forms
Metastatic lesions in skeleton	Increase in BMD in areas involved with metastasis from osteoblastic tumors
Vertebral compression fracture and vertebroplasty	Decrease in vertebral height and conversely increase in mineral density if compression fracture exists Unusually high vertebral BMD and statistical indices as well as blackening of vertebra on the DXA image in vertebroplasty
Laminectomy	Decrease in BMD of lumbar vertebrae due to removal of bony structures
Scan acquisition	
Positioning	Changes in BMD values and diagnosis Inconsistency of measurements in serial studies Higher likelihood of motion during scanning
Motion	Visualized as a single break or one with regular pattern Error in bone mapping and BMD measurements
Image noise	Uncertainty in measurements of the lumbar spine BMD, in particular, in obese patients
Data processing	
Problems with calibration using phantoms	Systematic inaccuracy in measurements, if calibration factor not properly set during installation or service
Error in patient data entry	Incorrect selection of normal reference database according to patient age, gender, and ethnicity, thus erroneous statistical indices provided
ROI placement and bone map error	Error in BMD of vertebrae due to incorrect labeling Change in BMD of a bone or bone subregion by both erroneous soft tissue inclusion or bone exclusion during bone mapping Diminished reproducibility

A

DXA Results Summary:

Region	Area (cm²)	BMC (g)	BMD (g/cm²)	T - score	PR (%)	Z - score	AM (%)
L1	12.14	11.03	0.909	-0.1	98	0.6	108
L2	13.38	13.56	1.014	-0.1	99	0.7	108
L3	13.36	12.84	0.961	-1.1	89	-0.3	97
L4	13.72	18.55	1.352	2.1	121	3.0	133
Total	52.60	55.99	1.064	0.2	102	1.0	111

B

DXA Results Summary:

Region	Area (cm²)	BMC (g)	BMD (g/cm²)	T - score	PR (%)	Z - score	AM (%)
L1	14.14	3.14	0.222	-6.4	24	-4.5	31
L2	15.74	1.77	0.112	-8.3	11	-6.3	14
L3	17.17	2.47	0.144	-8.5	13	-6.4	17
L4	17.48	2.58	0.148	-8.8	13	-6.6	17
Total	64.52	9.96	0.154	-8.1	15	-6.0	19

C

DXA Results Summary:

Region	Area (cm²)	BMC (g)	BMD (g/cm²)	T - score	PR (%)	Z - score	AM (%)
L1	11.63	6.49	0.558	-4.1	55	-4.1	55
L2	10.85	6.78	0.625	-4.3	57	-4.3	57
L3	14.19	8.90	0.627	-4.3	57	-4.3	57
L4	16.81	11.38	0.677	-4.3	59	-4.3	59
Total	53.48	33.55	0.627	-4.2	58	-4.2	58

Figure 1 (A-C): (A) An oval-shaped density from a metallic button of trousers is in ROI of L4, probably mistaken for a focal degenerative process. In densitometric results, the *T*-score of the L4 vertebra is much higher than those of others. (B and C) Scanning shortly and long after ingestion of the barium for diagnostic radiologic procedures. When recently ingested, the colonic haustrations are readily recognizable. Conversely, long thereafter, barium may be faintly visualized

DXA Results Summary:

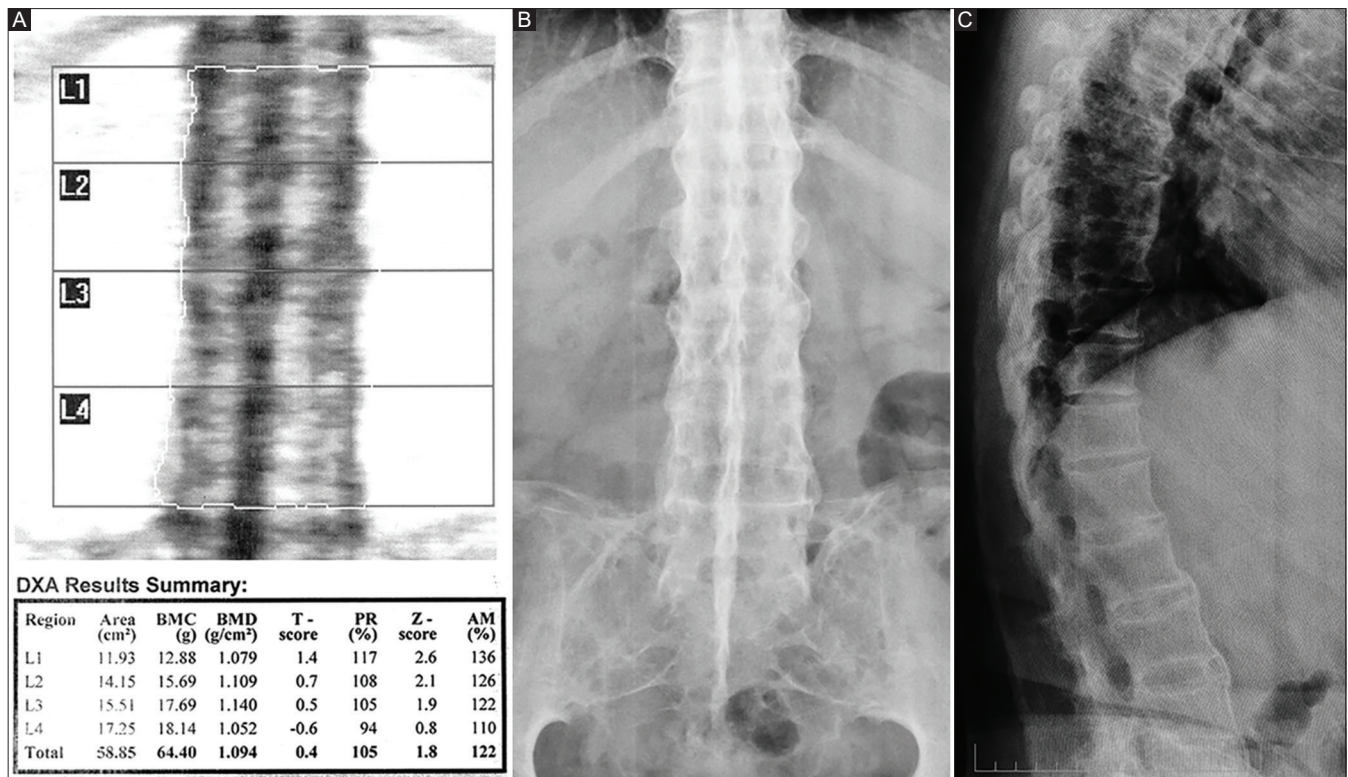| Region	Area (cm²)	BMC (g)	BMD (g/cm²)	T-score	PR (%)	Z-score	AM (%)
L1	11.93	12.88	1.079	1.4	117	2.6	136
L2	14.15	15.69	1.109	0.7	108	2.1	126
L3	15.51	17.69	1.140	0.5	105	1.9	122
L4	17.25	18.14	1.052	-0.6	94	0.8	110
Total	58.85	64.40	1.094	0.4	105	1.8	122

Figure 2 (A-C): (A) DXA scan shows significant fusion of the lumbar vertebrae in a way that vertebrae are poorly delineated. In posteroanterior (B) and lateral (C) views of the plain X-ray images, the classic pattern of AS (as mentioned in the text) is present. In the lateral view, the neighboring vertebrae are fused in anterior aspect of the body through a calcified anterior ligament

Factors Pertinent to Patient Preparation and Conditions/Issues before Scan

There is a diverse range of conditions and disorders related to the patients undergoing DXA scanning, including skeletal disorders and prior surgeries, which affects densitometric measurement. In this section, the impact of some of the less common and rare skeletal disorders and surgical interventions as well as the effect of poor preparation, for example, recent barium ingestion, and also metallic objects on the patient's garments or pierced to the patient's skin, whether removable or not, are discussed.

Generally recommended, before beginning the procedure, the patient is asked to remove their garments with metallic buttons, zippers, jewelry, or other items with studded metallic objects. They are also asked to empty their pockets of items that may superimpose on the bones at the region of interest and pose a negative impact in the image because of their high density, for example, keys, coins, etc.[1] There are other conditions that may interfere with densitometry which are not removable before the scan. Retained barium in the bowels ingested from radiologic procedures during the past few days is another issue because of interference with the densitometry of the spine. Since the barium in the colonic lumen conforms to the anatomy of the colonic haustrations, the pattern is readily recognizable.

Overlapping on the lumbar vertebrae leads to erroneous measurements and bizarre results. The conditions above should be sought before performing scan through interview with and examination of the patient [Figure 1].[1-3]

An important but rare disorder closely related to the degenerative processes of the bones and joints is ankylosing spondylitis (AS). Inflammation of the skeleton and connective tissues, mainly spine, leads to progressive calcification of the longitudinal ligaments and other peri-spinal soft tissues and joints. When fully developed, the vertebrae cannot be delineated owing to vertebral fusion "bamboo spine" and the calcified ligaments "dagger spine" interfere with densitometric measurements [Figure 2].[4-6]

Lumbar spine and proximal femur are sites frequently involved in metastatic disease. Focal zones with increased mineral density scattered at the regions of interest from osteoblastic or sclerotic neoplasms, that is, prostate or breast cancers, may falsely elevate the overall BMD of that region [Figure 3].[2,7]

Osteoporosis poses the patients at an increased risk of fracture. In lumbar vertebrae, fracture leads to impaction of bony structure and thus elevation in the regional mineral concentration but no change in the absolute mineral content. Patients with compression fracture may undergo
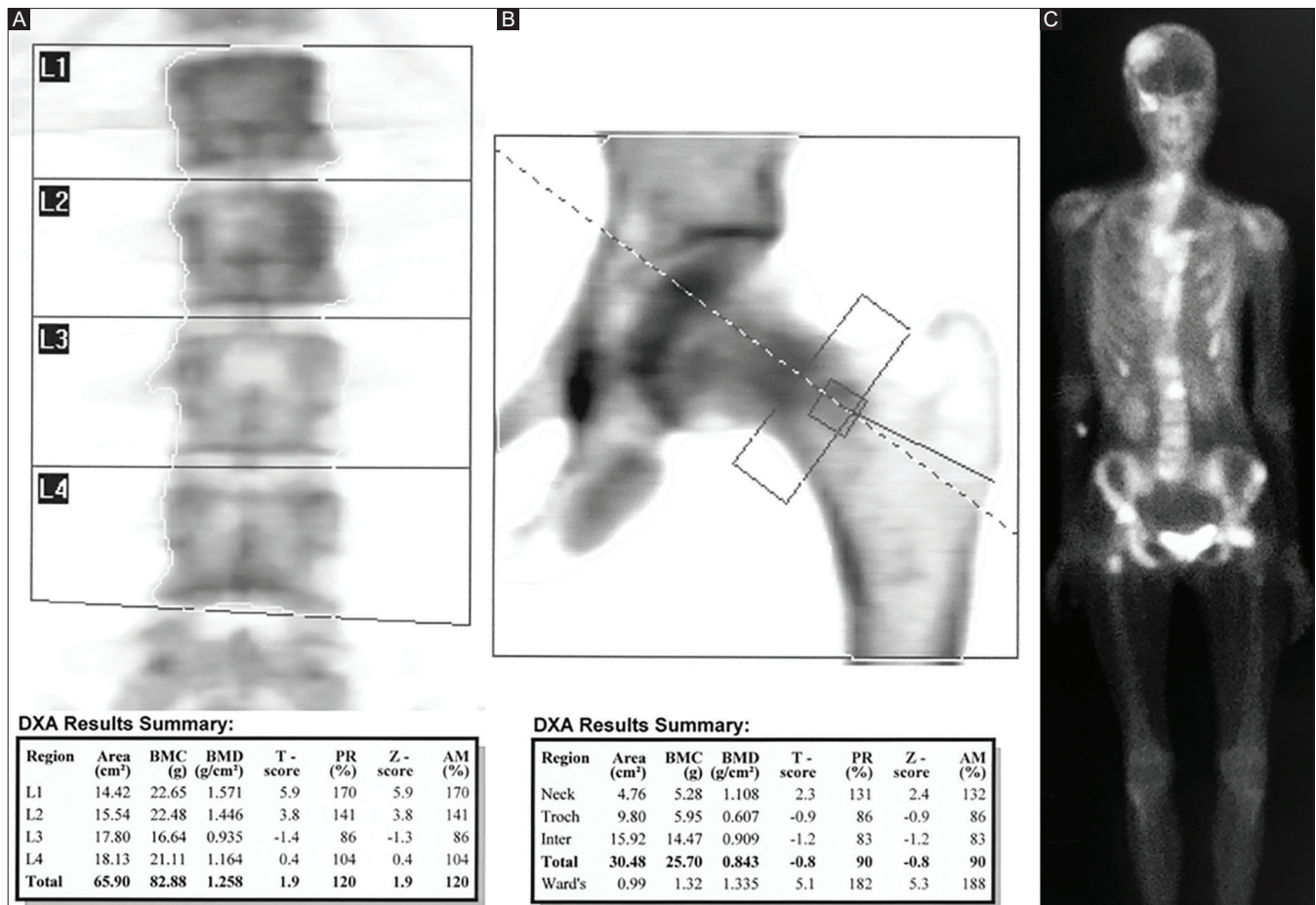
DXA Results Summary: (A)

Region	Area (cm²)	BMC (g)	BMD (g/cm²)	T - score	PR (%)	Z - score	AM (%)
L1	14.42	22.65	1.571	5.9	170	5.9	170
L2	15.54	22.48	1.446	3.8	141	3.8	141
L3	17.80	16.64	0.935	-1.4	86	-1.3	86
L4	18.13	21.11	1.164	0.4	104	0.4	104
Total	65.90	82.88	1.258	1.9	120	1.9	120

DXA Results Summary: (B)

Region	Area (cm²)	BMC (g)	BMD (g/cm²)	T - score	PR (%)	Z - score	AM (%)
Neck	4.76	5.28	1.108	2.3	131	2.4	132
Troch	9.80	5.95	0.607	-0.9	86	-0.9	86
Inter	15.92	14.47	0.909	-1.2	83	-1.2	83
Total	30.48	25.70	0.843	-0.8	90	-0.8	90
Ward's	0.99	1.32	1.335	5.1	182	5.3	188

Figure 3 (A-C): (A and B) In the DXA scan, focal zones with higher density are evident in the left hip region. The L1 and L2 vertebrae are also involved totally and partially respectively. In densitometric results, these two vertebrae show significantly higher mineral density and *T*-score. Bone scan (C) confirms the presence of widespread metastatic involvement of the skeleton

vertebroplasty to stabilize the spine through injecting special materials or cement into the vertebral body. On DXA images, the cement is visible as a highly dense material, revealing a far higher attenuation than many nonartificial causes of increased bone density [Figure 4].[1,8,9]

Laminectomy, as surgical removal of lamina and spinous processes of one or more vertebrae, is rarely observed in DEXA scanning but merits an extra attention, because of its consequence in reducing the regional mineral density and thus overdiagnosis [Figure 5].[2,9]

Factors Pertinent to Scan Acquisition

Positioning
It is recommended to use standard positioners to place the organ of interest in the correct position suitable for densitometry scanning. Positioning aids include knee positioner and foot restraint or hip positioner. The spine should be placed straight in the middle of the scanning area, without bending or axial rotation. Off-center position of the spine in the scan area should be avoided. Moreover, the natural lordosis of the lumbar spine should

be minimized by applying a positioner in order to flex the hip joints at right angle, as close as to 90°. The patient is asked to lay his or her arms out of field of view and not keep them over the stomach. For scanning the hip or femoral regions, a specific positioner is designed and supplied by the manufacturer to strap the foot to, to place the leg internally rotated, by using a Velcro® strap. The rationale for such positioning is to make the longitudinal axis of the femoral neck parallel to the detector surface of scanning plane. Thus, the incident photons will hit the bone perpendicularly. Besides, minimum depth of bone tissue and maximum surface are face to the X-ray beam. Lesser trochanter is used as a general and imprecise marker for sufficiency of degree of internal rotation. This standardization helps to maintain consistency of measurements in serial studies as well. Nonconformity to this rule may lead to some changes in the BMD values and thus the diagnosis. Securing the foot to the positioner also minimizes the unintentional movements during scanning. In addition to sufficient internal rotation, the shaft of the femur should be placed straight, parallel to the long axis of the scanning table, without obvious abduction or adduction [Figure 6].[1,9-14]
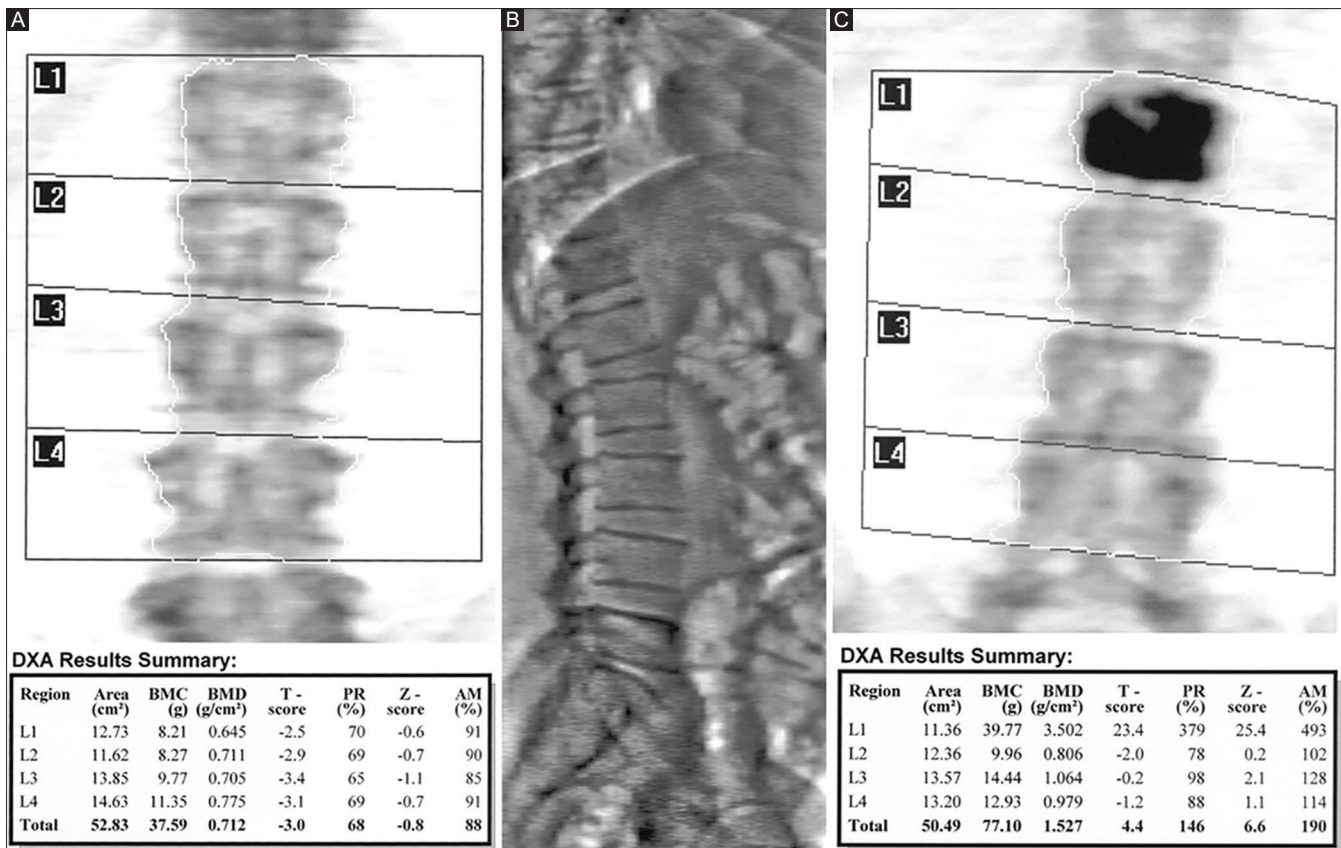
DXA Results Summary: (A)

Region	Area (cm²)	BMC (g)	BMD (g/cm²)	T - score	PR (%)	Z - score	AM (%)
L1	12.73	8.21	0.645	-2.5	70	-0.6	91
L2	11.62	8.27	0.711	-2.9	69	-0.7	90
L3	13.85	9.77	0.705	-3.4	65	-1.1	85
L4	14.63	11.35	0.775	-3.1	69	-0.7	91
Total	52.83	37.59	0.712	-3.0	68	-0.8	88

DXA Results Summary: (C)

Region	Area (cm²)	BMC (g)	BMD (g/cm²)	T - score	PR (%)	Z - score	AM (%)
L1	11.36	39.77	3.502	23.4	379	25.4	493
L2	12.36	9.96	0.806	-2.0	78	0.2	102
L3	13.57	14.44	1.064	-0.2	98	2.1	128
L4	13.20	12.93	0.979	-1.2	88	1.1	114
Total	50.49	77.10	1.527	4.4	146	6.6	190

Figure 4 (A-C): (A) With meticulous attention, the higher density of the T12 vertebra may catch the technician's eye. In the lateral view of the spine (B) (IVA or VFA as mentioned in the text) verifies compression fracture in T12 vertebra. (C) A scan with prior vertebroplasty in L1 is presented. The cement placed in the body demonstrates a considerably higher density (a *T*-score of higher than 23). These two entities are readily distinguishable

Motion

The patient should be positioned in a comfortable manner on the scanning table to minimize the probability of occurrence of motion during the scanning. The patient should also be requested to remain still to reduce the potential effect of motion on the densitometric results. A swift jerky movement, voluntary or involuntary as result of cough or sneeze, may be visualized as a break in the bone or "smudge on the image" representing a shift of the pixels. Motion due to breathing may cause the same pattern of image distortion but regular and less severe. The artifact may be appeared as repetitive horizontal lines and breaks in sinusoidal pattern in synchrony with the respiration. Maximization of patient comfort is a helpful tactic to reduce the occurrence of such problem [Figure 7].[1,10,11]

Image noise

The DXA scanning employs X-ray photons with two different energies, 100 kV and 140 kV in HOLOGIC® scanners, to differentiate the bone and soft tissue by providing different attenuation profiles or maps. Ionizing photons bear attenuation while traversing the body tissues of the patient being scanned before detection in the detector. In obese individuals, extra soft tissue superimposed, mainly, on the lumbar spine, strikingly different from patient with average-sized body habitus, may exert an adverse effect on the calculations of the mineral content of the lumbar vertebrae. The uncertainty may even arise as a result of greater amount of noise in the image [Figure 8].[1,10]

Factors Pertinent to Data Processing

Problems with calibration using quality control phantoms

As discussed above, after creation of attenuation profiles by dual-energy photons, to convert the data in the form of attenuation map to bone mineral content (BMC) in grams, a calibration factor is applied, as below equation:

$$BMC(g) = \mu(cm^{-1}) \times Calibration\ factor$$

BMC (g) in every pixel in the DXA image is the product of both factors. This factor is calculated during manufacturing by applying standard phantoms of the spine and hip with known density or its equivalent mineral content based on the specifications of the device, particularly the energy of the X-ray photons, and is installed on the computer of the device. These phantoms simulate those regions in individuals with average body habitus. As long as the daily quality control is passed, the built-in calibration factor is applicable to measurements in clinical setting. As a criterion for proper
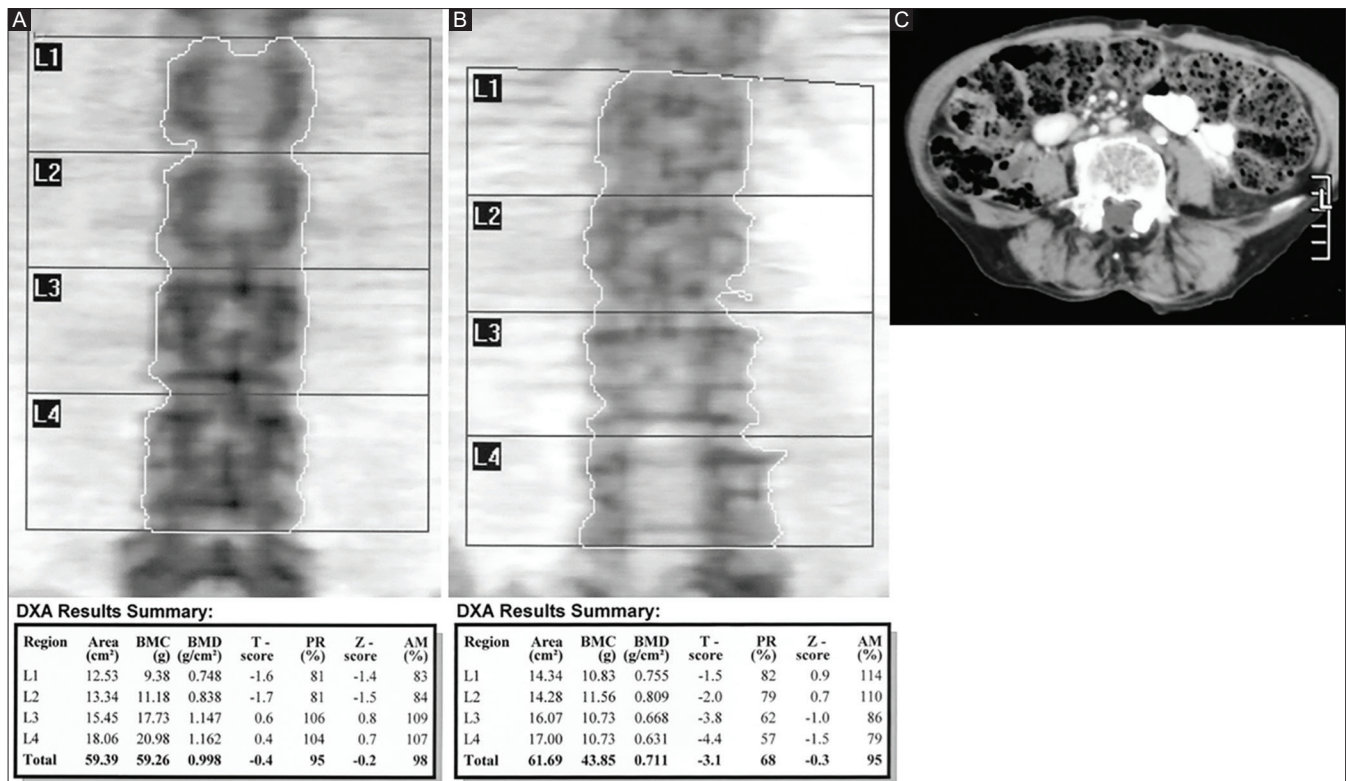
DXA Results Summary (A):

Region	Area (cm²)	BMC (g)	BMD (g/cm²)	T-score	PR (%)	Z-score	AM (%)
L1	12.53	9.38	0.748	-1.6	81	-1.4	83
L2	13.34	11.18	0.838	-1.7	81	-1.5	84
L3	15.45	17.73	1.147	0.6	106	0.8	109
L4	18.06	20.98	1.162	0.4	104	0.7	107
Total	59.39	59.26	0.998	-0.4	95	-0.2	98

DXA Results Summary (B):

Region	Area (cm²)	BMC (g)	BMD (g/cm²)	T-score	PR (%)	Z-score	AM (%)
L1	14.34	10.83	0.755	-1.5	82	0.9	114
L2	14.28	11.56	0.809	-2.0	79	0.7	110
L3	16.07	10.73	0.668	-3.8	62	-1.0	86
L4	17.00	10.73	0.631	-4.4	57	-1.5	79
Total	61.69	43.85	0.711	-3.1	68	-0.3	95

Figure 5 (A-C): (A and B) Two DXA scans with prior laminectomy in upper and lower lumbar spine. These findings may go unnoticed to less experienced eyes. In the densitometric results, the affected vertebrae reveal a considerable decrease in the overall mineral density and *T*-scores and thus misclassified as osteopenia or osteoporosis. (C) The computed tomography at the level of lumbar spine shows absence of the posterior elements of the vertebra

functioning of the device, the result of the QC each day is compared to, say, 10 measurements of calibration during installation of the device as a mean value displayed on the QC plot. These values are used as reference for future data comparisons. Thus, the results of BMD attained by applying an accurate CF depict the clinical factors involved versus the drift of the scanner. A significant deviation of the result of daily QC test, in HOLOGIC® systems, beyond the limits of ±1.5% of the mean, indicates the need for a new calibration. Fortunately, now, the scanners are equipped with a self-calibration facility to continuously monitor the status and calibrate the device during patient scanning by using a built-in calibration drum, particularly for the variations of the production of the X-ray photons in the tube. Moreover, other sources of error may cause a failed QC test, including improper positioning of the phantom on the scanning table, inaccurate analysis of the image of the scanned phantom, or even as a result of a physical damage in the phantom. It is obvious that every phantom must be used for the device designed and fabricated by the same manufacturer. Although rare, an error in the calculated calibration factor or a change after a major service could result in a systematic error in calculation of BMC [Figure 9].[10,11]

Error in patient data entry
After calculation of the BMC and area, as number of pixels bound by the bone region of interest on the image, the BMD (g/cm²) is computed and then is compared with the corresponding values of the normal healthy population embedded in computer as normal reference databases. For spine, the normal reference database includes the information of the vertebrae from L1 to L4 as well as the total and likewise, for the hip, five subregions as neck, trochanteric, intertrochanteric, total, and Ward's area. These databases for spine and hip are constructed from different cohorts of individuals according to gender and ethnicity as well as for different age groups. By means of statistical comparison of the data of an index patient with the databases of the same sex, same race, and either young adult or same age, statistical parameters as *T*- and *Z*-scores are generated, respectively. These parameters provide the physician the information of the relative standing of the patient compared to young healthy adults and his or her peers. The data are also presented graphically in the final report based on *T*-score and on the curves based on *Z*-score. Hence, if the technician fails to select the appropriate gender and ethnicity and also to enter the correct age of the patient or birth date, an unsuitable database is chosen and so that the results are unacceptable. For age, in some countries, specific calendars other than Gregorian calendar may be in use and thus the inter-calendar conversion of date of birth may cause occasional mistake. Lack of data or erroneous information regarding menopausal status in female patients lead to inappropriate selection of available criteria, WHO versus
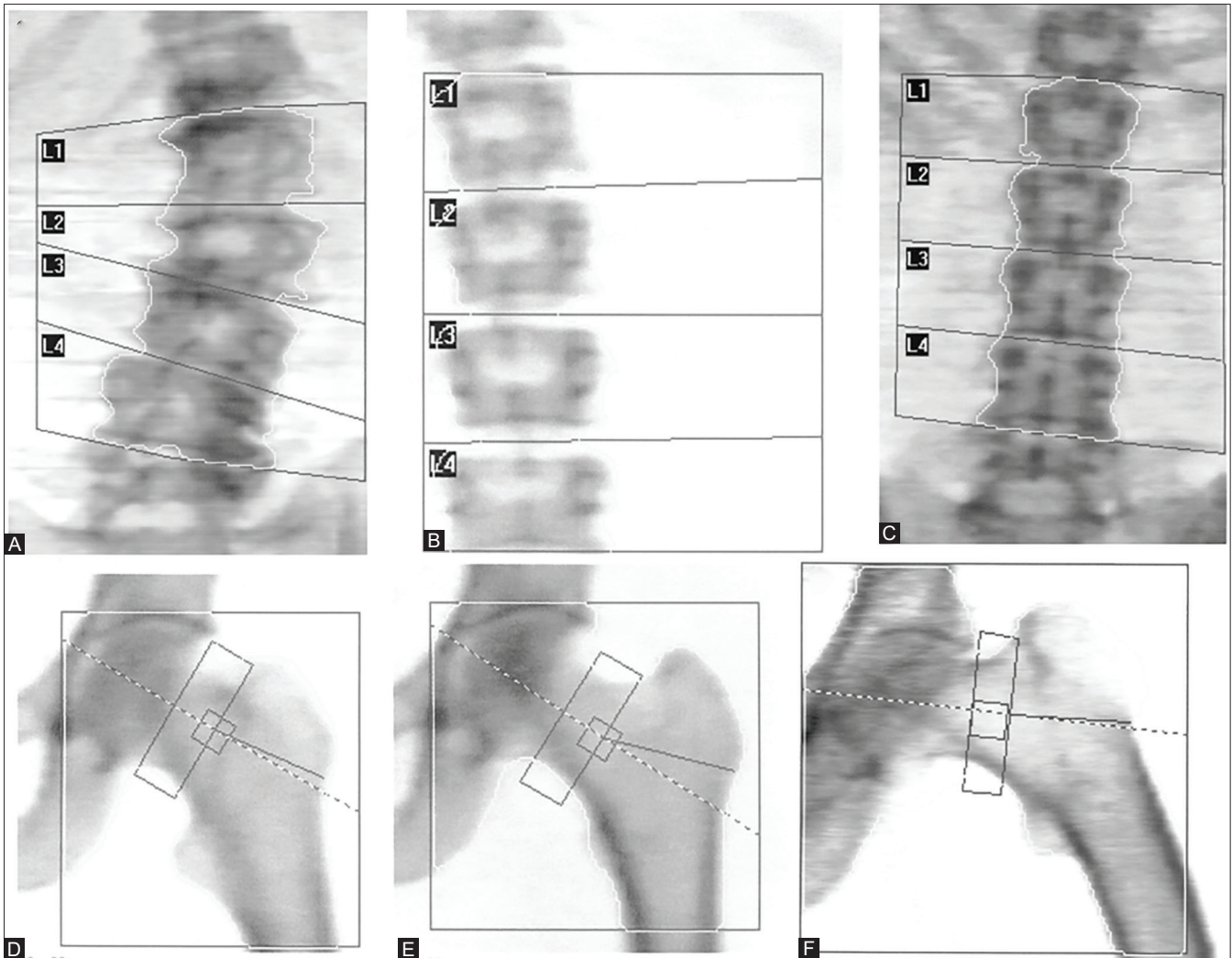
Figure 6 (A-F): Various mispositioning of the spine and hip; marked spinal bending as a result of degeneration (A), off-center spine during acquisition (B), patient's hands resting on the chest resembling the ribs (C), insufficient (D), and sufficient (E) internal rotation of the leg, striking abduction of the leg (F)
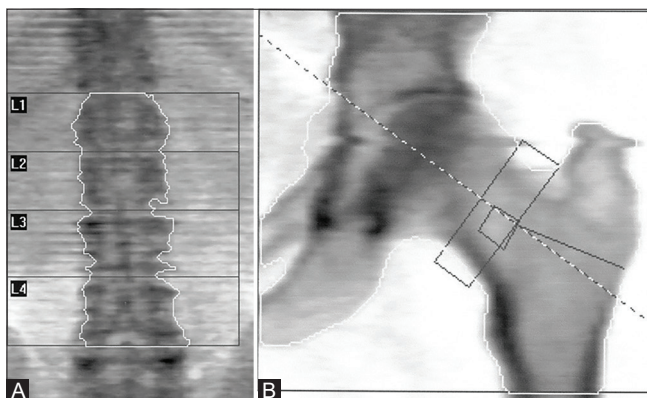
Figure 7 (A and B): (A) Regular horizontal lines during the scan as a result of rapid deep breathing of the patient. (B) A swift jerky movement occurred almost in the middle of the scanning of the hip region. The pattern is similar to a smudge on the image from right to left

ISCD, for diagnostic classification and also for estimation of the fracture risk by FRAX® algorithm [Figure 10].[10-12]

ROI placement and Bone map error

After checking the quality of scan, an important step is placing the regions of interest. In lumbar spine, the vertebrae must be recognized and labeled correctly based on the site of the attachment of the 12th ribs, level of iliac crests, and also the configuration of the vertebrae. Then, the whole or global ROI and intervertebral lines should be placed accordingly. The next step, which plays even a more critical role, is drawing the bone map. In this process, which is associated with the concept of segmentation in image processing, the edges of the bones are detected automatically and thus the bone is separated from the neighboring soft tissue. Least operator intervention in this process maximizes the reproducibility in serial scans. Before proceeding to analysis and generating the result, the technician must verify the correctness of the bone map. Minor errors like small holes, remained at the region of bone map or small zones or "islands" mapped as bone outside the bone map, are less critical to be resolved. However, there are options

in dedicated software packages that automatically resolve them, for instance, in HOLOGIC® software, "Fill Holes" and "Sink Islands" are designed for such problems. Any major error in mapping of a bone may lead to a notable change in the area and therefore the bone mineral density of that bone. In some occasions, as a result of decreased mineral content of the bone, differentiation from the neighboring soft tissue may be compromised. Therefore, the corresponding bone

may not be correctly mapped and some parts may be cut out. Conversely, parts of soft tissue may be included in the map of bone. All this issues result in erroneous density measurements and requires manual correction by the operator [Figures 11 and 12].[9-13]

Conclusion/Take-Home Messages

Correct technique of conducting DXA scans is prior to and a prerequisite for a correct interpretation. In DXA scanning, factors that are able to potentially affect the results may be organized in three different categories, including preparation, acquisition, and processing. In each category, there are multiple factors, as listed above, that create uncertainties and fallacies to different extents. Some are visualized as an imaging artifact in the DXA
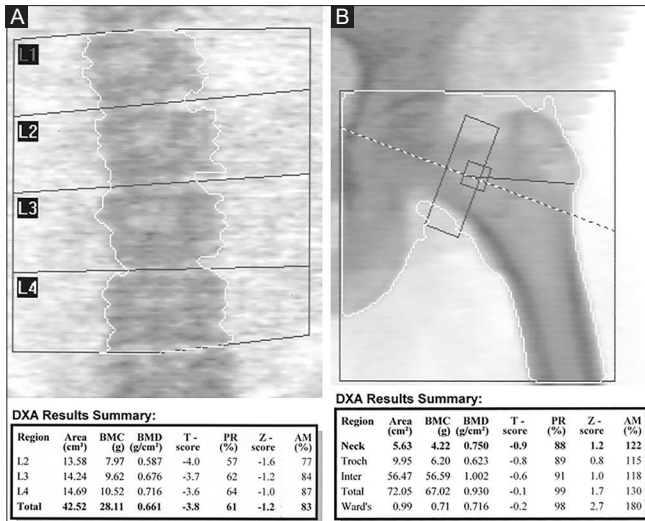
DXA Results Summary: (Figure 8A)

Region	Area (cm²)	BMC (g)	BMD (g/cm²)	T-score	PR (%)	Z-score	AM (%)
L2	13.58	7.97	0.587	-4.0	57	-1.6	77
L3	14.24	9.62	0.676	-3.7	62	-1.2	84
L4	14.69	10.52	0.716	-3.6	64	-1.0	87
Total	42.52	28.11	0.661	-3.8	61	-1.2	83

DXA Results Summary: (Figure 8B)

Region	Area (cm²)	BMC (g)	BMD (g/cm²)	T-score	PR (%)	Z-score	AM (%)
Neck	5.63	4.22	0.750	-0.9	88	1.2	122
Troch	9.95	6.20	0.623	-0.8	89	0.8	115
Inter	56.47	56.59	1.002	-0.6	91	1.0	118
Total	72.05	67.02	0.930	-0.1	99	1.7	130
Ward's	0.99	0.71	0.716	-0.2	98	2.7	180

Figure 8 (A and B): (A) In this obese patient, the image of the lumbar spine seems grainy in texture and also the edges of the bony tissues seem like irregular sawtooth. (B) Substantial amount of fat of the abdomen is superimposed on the iliac bone and femoral head and neck. As can be seen, these regions show grainy texture as well, but the remaining part of the femur reveals a uniform and smooth appearance. When a high amount of soft tissue is overlapped on the regions of interest, the contouring may be compromised and thus some parts of soft tissue may be included in the bone map (shown by arrowhead)
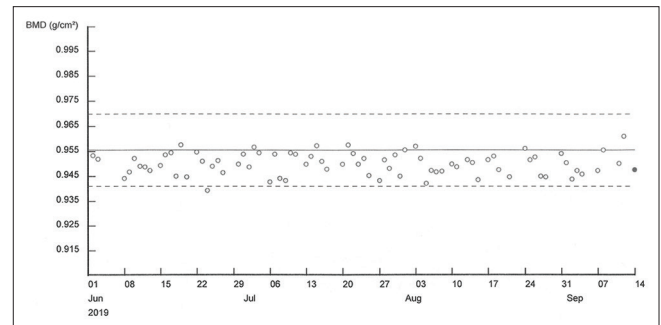
Figure 9: Plot of daily QC using spine phantom from June 1 to September 14. Vertical axis denotes the BMD of the phantom and the horizontal axis represents time. Each circle corresponds to the result of a specific day. Preferably, the circles should lay between two horizontal lines (dashed lines) as 95% confidence interval around the mean (solid horizontal line) measured during installation. The solid circle signifies the result of the last day the QC procedure is performed

DXA Results Summary: (top left)

Region	Area (cm²)	BMC (g)	BMD (g/cm²)	T-score	PR (%)	Z-score	AM (%)
Neck	4.52	2.64	0.584	-2.4	69	-1.5	78
Troch	9.46	4.42	0.467	-2.3	66	-1.8	72
Inter	13.29	10.69	0.804	-1.9	73	-1.5	77
Total	27.28	17.75	0.651	-2.4	69	-1.8	75
Ward's	1.11	0.53	0.476	-2.2	65	-0.7	86

DXA Results Summary: (top right)

Region	Area (cm²)	BMC (g)	BMD (g/cm²)	T-score	PR (%)	Z-score	AM (%)
Neck	4.52	2.64	0.584	-2.4	69	-2.0	72
Troch	9.46	4.42	0.467	-2.3	66	-2.2	68
Inter	13.29	10.69	0.804	-1.9	73	-1.8	74
Total	27.28	17.75	0.651	-2.4	69	-2.2	71
Ward's	1.11	0.53	0.476	-2.2	65	-1.5	74

DXA Results Summary: (bottom left)

Region	Area (cm²)	BMC (g)	BMD (g/cm²)	T-score	PR (%)	Z-score	AM (%)
Neck	5.18	4.02	0.776	-1.1	83	0.4	108
Troch	11.21	8.01	0.714	-0.5	92	0.2	105
Inter	22.06	25.11	1.138	-0.3	95	0.7	113
Total	38.45	37.14	0.966	-0.4	93	0.6	111
Ward's	1.24	0.99	0.801	0.1	102	2.4	174

DXA Results Summary: (bottom right)

Region	Area (cm²)	BMC (g)	BMD (g/cm²)	T-score	PR (%)	Z-score	AM (%)
Neck	5.18	4.02	0.776	-0.7	91	1.7	132
Troch	11.21	8.01	0.714	0.1	102	1.9	137
Inter	22.06	25.11	1.138	0.2	103	2.1	140
Total	38.45	37.14	0.966	0.2	103	2.3	141
Ward's	1.24	0.99	0.801	0.6	109	3.6	211

Figure 10: Bone mineral density results of the proximal femur of a patient aged 52 (top left) and the results when date of birth is mistakenly entered (here, age of 42) (top right). As can be seen, *T*-scores remained the same but *Z*-scores decreased as the patient data are compared to younger healthy adults. Data of a male patient (bottom left) compared to that when the sex is entered as female. The *T*- and *Z*-scores are increased. These errors result in, occasionally, a change in the diagnosis

Figure 11 (A-C): (A) The region of interest and bone map is placed correctly. (B) The ROI and bone map drawn initially by automatic option of softwa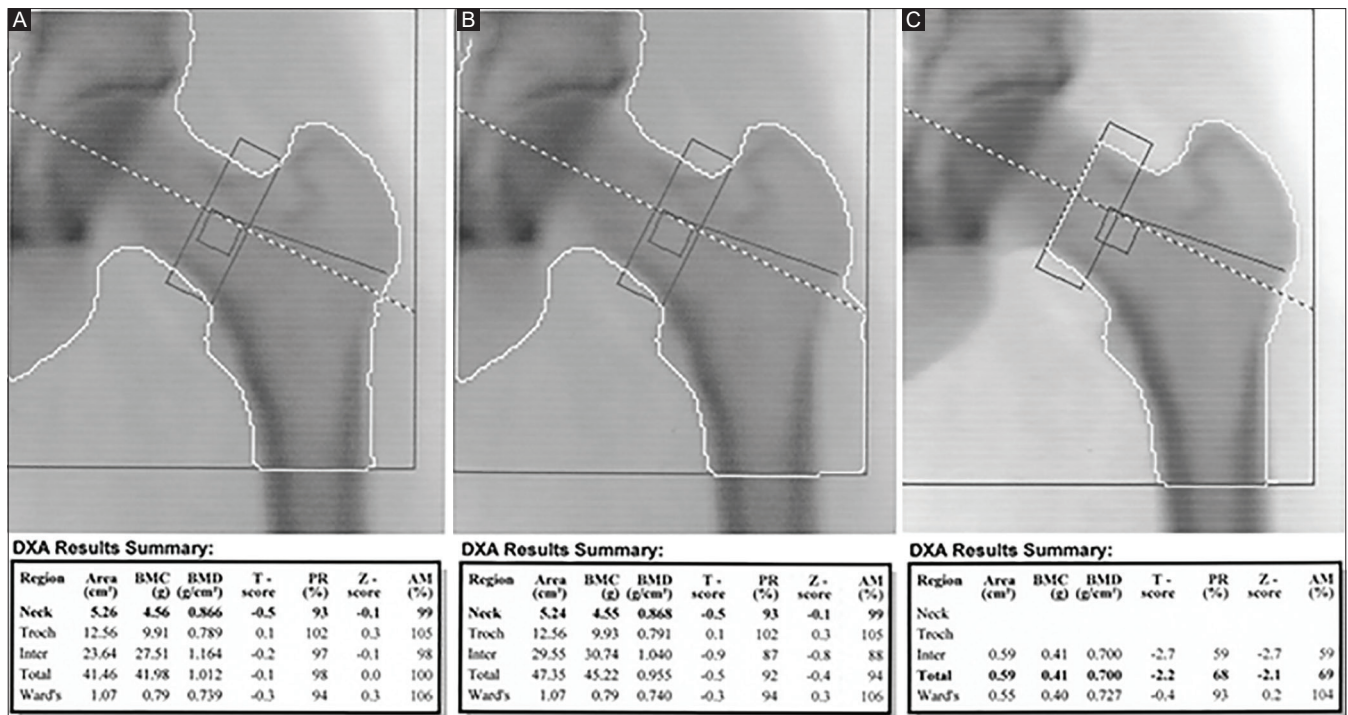re. Some parts of soft tissue adjacent femoral shaft are included. This finding seems subtle enough to remain hidden from a technician's or physician' eyes. The consequence is evident in the density and *T*-score of the total femur compare to corresponding values in (A). (C) Another analysis of the hip region of the same patient by the software excluded some necessary parts of the hip. In such situations, no data would be available in the table of densitometric results
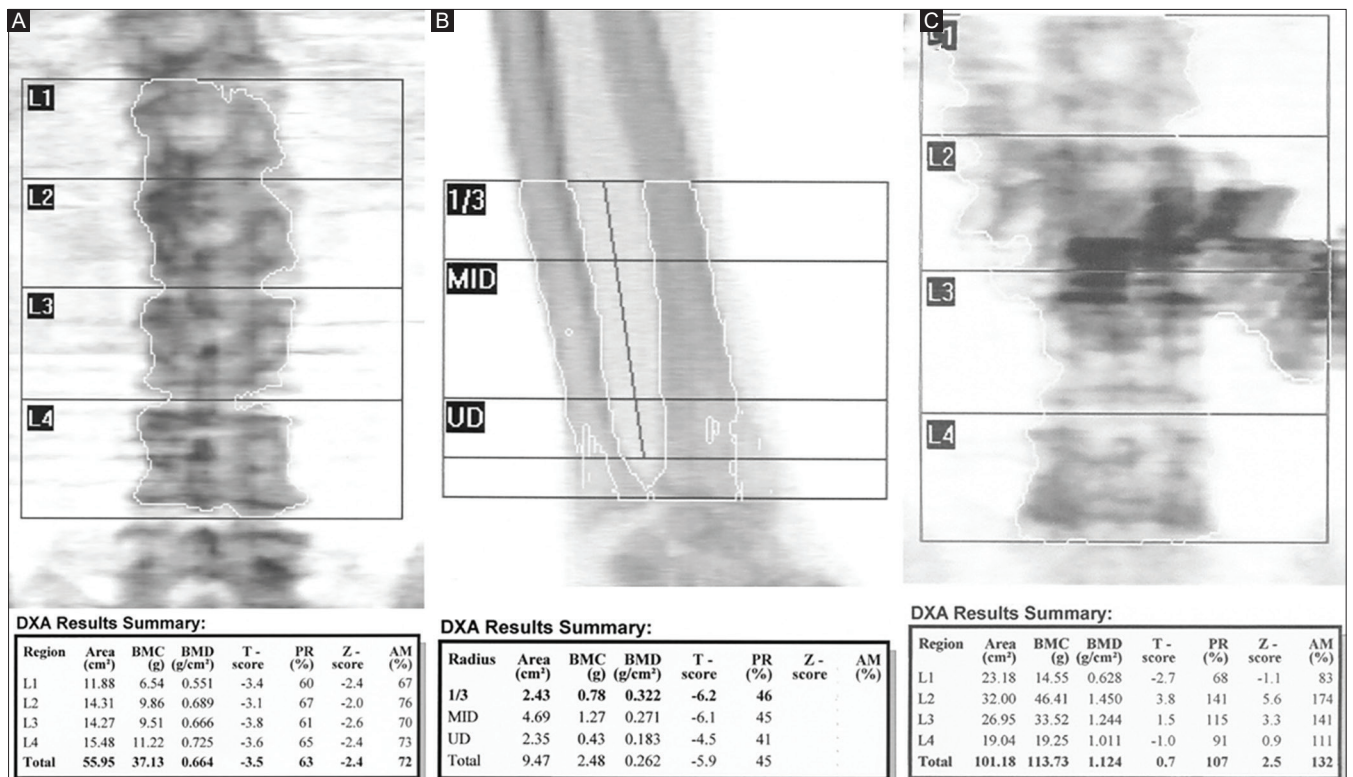
A — DXA Results Summary:

Region	Area (cm²)	BMC (g)	BMD (g/cm²)	T-score	PR (%)	Z-score	AM (%)
Neck	5.26	4.56	0.866	-0.5	93	-0.1	99
Troch	12.56	9.91	0.789	0.1	102	0.3	105
Inter	23.64	27.51	1.164	-0.2	97	-0.1	98
Total	41.46	41.98	1.012	-0.1	98	0.0	100
Ward's	1.07	0.79	0.739	-0.3	94	0.3	106

B — DXA Results Summary:

Region	Area (cm²)	BMC (g)	BMD (g/cm²)	T-score	PR (%)	Z-score	AM (%)
Neck	5.24	4.55	0.868	-0.5	93	-0.1	99
Troch	12.56	9.93	0.791	0.1	102	0.3	105
Inter	29.55	30.74	1.040	-0.9	87	-0.8	88
Total	47.35	45.22	0.955	-0.5	92	-0.4	94
Ward's	1.07	0.79	0.740	-0.3	94	0.3	106

C — DXA Results Summary:

Region	Area (cm²)	BMC (g)	BMD (g/cm²)	T-score	PR (%)	Z-score	AM (%)
Neck							
Troch							
Inter	0.59	0.41	0.700	-2.7	59	-2.7	59
Total	0.59	0.41	0.700	-2.2	68	-2.1	69
Ward's	0.55	0.40	0.727	-0.4	93	0.2	104

Figure 12 (A-C): (A) In this image, some parts of the bone are excluded from the bone map as a result of significant hypodensity of the bone. The consequence is false elevation of the bone mineral density and *T*-score. (B) Similar findings in the forearm region as that in (A). (C) The patient has ingested barium and now the barium in the transverse colon overlaps the lumbar spine. The vertebral lines are drawn correctly but the bone map includes areas with barium retention in the colon as parts of bony tissues

A — DXA Results Summary:

Region	Area (cm²)	BMC (g)	BMD (g/cm²)	T-score	PR (%)	Z-score	AM (%)
L1	11.88	6.54	0.551	-3.4	60	-2.4	67
L2	14.31	9.86	0.689	-3.1	67	-2.0	76
L3	14.27	9.51	0.666	-3.8	61	-2.6	70
L4	15.48	11.22	0.725	-3.6	65	-2.4	73
Total	55.95	37.13	0.664	-3.5	63	-2.4	72

B — DXA Results Summary:

Radius	Area (cm²)	BMC (g)	BMD (g/cm²)	T-score	PR (%)	Z-score	AM (%)
1/3	2.43	0.78	0.322	-6.2	46		
MID	4.69	1.27	0.271	-6.1	45		
UD	2.35	0.43	0.183	-4.5	41		
Total	9.47	2.48	0.262	-5.9	45		

C — DXA Results Summary:

Region	Area (cm²)	BMC (g)	BMD (g/cm²)	T-score	PR (%)	Z-score	AM (%)
L1	23.18	14.55	0.628	-2.7	68	-1.1	83
L2	32.00	46.41	1.450	3.8	141	5.6	174
L3	26.95	33.52	1.244	1.5	115	3.3	141
L4	19.04	19.25	1.011	-1.0	91	0.9	111
Total	101.18	113.73	1.124	0.7	107	2.5	132

image and others may be inferred and understood from the quantitative results. High-density materials, metallic objects in or attached to body/garments, falsely increase BMD values due to higher radiation attenuation. Retained barium in bowels, if overlapped on the vertebrae, metastatic lesions in skeleton and vertebral compression fracture and vertebroplasty causes increase in BMD. Conversely, laminectomy leads to decrease in BMD. Positioning may change BMD values and diagnosis and also causes inconsistency of measurements in serial studies. ROI placement and bone map error by both erroneous soft tissue inclusion and bone exclusion during bone mapping make changes in BMD of a bone or bone subregion. To avoid such misleading interpretation, attempt to acquire a substantial pertinent knowledge is undeniable for daily good practice for both physicians and technologists.

Financial support and sponsorship
Nil.

Conflicts of interest
There are no conflicts of interest.

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