DXA Troubleshooting And Challenging Cases

Sarah L. Morgan, MD, RD, CCD
UAB
Larry Jankowski, CBDT
IBJI
COI Disclosures:

Sarah Morgan: MD, RD, CCD : None

Lawrence Jankowski CBDT: None
Course Objectives

• Reconsider the appropriateness of “image not for diagnostic use” disclaimer
• Review situations where the DXA images give clues to the diagnosis or mis-interpretation
• List common errors in DXA scanning and reporting with examples
Outline

• “image not for Diagnostic Use
• List the most common errors in DXA scanning with examples
  • Not labelling spinal levels appropriately
  • Not labelling spinal levels analogously on follow up scans
  • Differences in hip positioning

• Review situations where the DXA images give clues to the diagnosis (reconsider the appropriateness of “image not for diagnostic use” disclaimer.
  • Common artifacts
  • Problems in spine and hip analysis
  • Interval compression fracture
  • Show examples of specific disease processes seen on the DXA image.
“Image not for diagnostic use”

Where did this disclaimer come from?
Is it still valid?
History of Imaging in Bone Densitometry

• 1963 SPA - No image.

• 1980 - FDA approves first DPA device and requires the disclaimer: “Image not for diagnosis” to appear on all image printouts.

• 1986 FDA approves first pencil beam DXA

• Fan-beam DXA devices:
  • 1991 Linear scanning (transverse beam)
  • 1993 Rectilinear scanning (sagittal beam orientation)

• 2002 FDA approves Vert. Fx. Assessment

• 2007 FDA approves SE IVA for AAC

• 2017 FDA approves extended femur imaging for detection of AFF
Image Resolution Varies By Scanner

Digital XR
Horizon-HD VFA
Discovery-IVA
Prodigy
iDXA
Resolution Varies with Scan Mode
Image Post-processing Cannot Improve Resolution

• Image processing (window, level, interpolative smoothing, anti-aliasing) make image more pleasing to the eye

• Cannot create detail not present in raw data
Post-processing and Artifact Detection

DJD secondary scoliosis, especially at L3-L4. These vertebral levels were deleted from analysis.

Baseline

Follow-up
“Image not for diagnostic use”?
Image not for diagnostic use

• Disclaimer is not a mandate
• Images convey the veracity of the underlying BMD
• Comparing serial images compensates for lower resolution
• Synergy between BMD, images, and patient presentation
• Errors of omission if we ignore them
The most common DXA errors

**Spine Errors**
- Incorrect or inconsistent vertebral labeling
- Incorrect intervertebral space identification
- Unrecognized pathology or artifacts
- Unrecognized interval changes

**Hip Errors**
- Incorrect or inconsistent patient positioning
- Incorrect or inconsistent regions of interest sizes and placements
- Unrecognized pathology or artifacts

**Other Errors**
- Unappreciated or ignored serendipitous findings
- Discordance in changes at skeletal sites
- Results unexpected or mismatched to patient presentation
Problems with Intervertebral Marker Identification and Placements
Vertebral Level Identification

• Extra Lumbar Vertebral Body?
• Establish a vertebral body numbering convention in your center?
• ISCD recommendation is to count from sacrum upward

<table>
<thead>
<tr>
<th># of Lumbar</th>
<th>Lowest Pair of Ribs</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>T-11</td>
</tr>
<tr>
<td>4</td>
<td>5.3% (20)</td>
</tr>
<tr>
<td>5</td>
<td>7.2% (27)</td>
</tr>
<tr>
<td>6</td>
<td>0% (0)</td>
</tr>
<tr>
<td>Total</td>
<td>12.5% (47)</td>
</tr>
</tbody>
</table>

375 Patients with complete spine exams (assumes 12 thoracic vertebra and first rib on T1)
Mislabeling affects BMD and T-scores

- Can misclassify diagnosis
- Impedes ability to monitor with serial scanning
### Bone Loss

#### DXA Results Summary: Baseline

<table>
<thead>
<tr>
<th>Region</th>
<th>Area (cm²)</th>
<th>BMC (g)</th>
<th>BMD (g/cm²)</th>
<th>T-score</th>
<th>Z-score</th>
</tr>
</thead>
<tbody>
<tr>
<td>L1</td>
<td>13.72</td>
<td>12.68</td>
<td>0.924</td>
<td>0.0</td>
<td>0.8</td>
</tr>
<tr>
<td>L2</td>
<td>16.68</td>
<td>16.37</td>
<td>0.981</td>
<td>-0.4</td>
<td>0.5</td>
</tr>
<tr>
<td>L3</td>
<td>18.21</td>
<td>17.66</td>
<td>0.970</td>
<td>-1.0</td>
<td>-0.1</td>
</tr>
<tr>
<td>L4</td>
<td>20.17</td>
<td>17.27</td>
<td>0.856</td>
<td>-2.4</td>
<td>-1.4</td>
</tr>
<tr>
<td>Total</td>
<td>68.78</td>
<td>63.97</td>
<td>0.930</td>
<td>-1.1</td>
<td>-0.1</td>
</tr>
</tbody>
</table>

Total BMD CV 1.0%, ACF = 1.026, BCF = 0.997, TH = 5.927

#### DXA Results Summary: Follow-up

<table>
<thead>
<tr>
<th>Region</th>
<th>Area (cm²)</th>
<th>BMC (g)</th>
<th>BMD (g/cm²)</th>
<th>T-score</th>
<th>Z-score</th>
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<tbody>
<tr>
<td>L1</td>
<td>13.32</td>
<td>9.49</td>
<td>0.713</td>
<td>-1.9</td>
<td>-1.1</td>
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<td>L2</td>
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<td>-1.2</td>
<td>-0.2</td>
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<td>L3</td>
<td>16.92</td>
<td>16.26</td>
<td>0.961</td>
<td>-1.1</td>
<td>-0.1</td>
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<tr>
<td>L4</td>
<td>17.86</td>
<td>17.25</td>
<td>0.966</td>
<td>-1.4</td>
<td>-0.4</td>
</tr>
<tr>
<td>Total</td>
<td>61.87</td>
<td>55.39</td>
<td>0.895</td>
<td>-1.4</td>
<td>-0.4</td>
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</tbody>
</table>

Total BMD CV 1.0%, ACF = 1.026, BCF = 0.997, TH = 5.927
Bone Loss Imaging (cont)

The ISCD recommendation is to include all levels from pelvis to first set of ribs and count from pelvis upward, even if 6 non-rib bearing VB’s for consistency.
Different Levels Invalidates Serial Results

2007

2011
Auto-Analysis marker placement is imperfect.
Manual analysis is not always perfect
BMC Histogram may help or hinder line placement

- “Valleys” should represent intervertebral disks
- Osteophytes can turn valleys into peaks
Not Labeling Spinal Levels Appropriately

• Inconsistent or improper intervertebral labeling confounds
  • Identifying levels with pathology
  • Comparisons to prior or subsequent scans proper placement
  • Identification of vertebral height loss and incident vertebral deformities
Interval Compression
Fractures
Side by side image comparisons

- Modern scanners allow display of prior study (on right) to current exam during acquisition
- Mask of prior analysis copies heights and labels
- But not all facilities may know of this feature
Look for subtle visual changes

- Subtle change in appearance of L1
  - Incident mild wedge deformity?
  - Consider VFA or other imaging for verification?
  - Change in management?
- Serendipitous finding: Did patient have a cholecystectomy between exams
Unfortunately no VFA, but I think there is a radiograph.
Comparing Images and BMD data

The BMD of L1 went from the lowest to the highest.
Images in discordant and unexpected changes

Indications: Established osteoporosis with vertebral augmentation, follow-up on alendronate

Results: Osteopenia of the hip and osteoporosis at the spine. There has been a 5.3% increase in BMD at the spine and a 4.7% loss at the hip.

Changes of less than 5% are not considered to be statistically significant.

Impression: Improvement in bone mineral density on alendronate. The patient is encouraged to continue her current therapy and return for a repeat scan in two years.”
Differences in Hip Positioning
Differences in Hip Rotation and Abduction


- Lesser trochanteric profiles not same size and location
- Pelvic rim outline
- Pelvic bone measured within the femur neck box.
Synthesis of Images, BMD & Med Hx.

SLE, long-term GCC

Lt. FN: T-Score = +2.2
Rt. FN: T-Score = -1.3
Mean FN T-score = +0.4
Mean Tot T-score = -0.9
Where’s Waldo? – A case of TMI?

### ANCILLARY RESULTS [DualFemur]

<table>
<thead>
<tr>
<th>Region</th>
<th>BMD (g/cm²)</th>
<th>Young-Adult (%)</th>
<th>Age-Matched (%)</th>
<th>BMC (g)</th>
<th>Area (cm²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Neck Left</td>
<td>0.752</td>
<td>70</td>
<td>-2.4</td>
<td>83</td>
<td>-1.2</td>
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<tr>
<td>Neck Right</td>
<td>0.891</td>
<td>83</td>
<td>-1.4</td>
<td>99</td>
<td>-0.1</td>
</tr>
<tr>
<td>Neck Mean</td>
<td>0.823</td>
<td>77</td>
<td>-1.9</td>
<td>91</td>
<td>-0.6</td>
</tr>
<tr>
<td>Neck Diff.</td>
<td>0.139</td>
<td>13</td>
<td>1.1</td>
<td>15</td>
<td>1.1</td>
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<tr>
<td>Upper Neck Left</td>
<td>0.591</td>
<td>65</td>
<td>-2.5</td>
<td>80</td>
<td>-1.1</td>
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<tr>
<td>Upper Neck Right</td>
<td>0.721</td>
<td>79</td>
<td>-1.5</td>
<td>98</td>
<td>-0.1</td>
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<tr>
<td>Upper Neck Mean</td>
<td>0.656</td>
<td>72</td>
<td>-2.0</td>
<td>89</td>
<td>-0.6</td>
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<tr>
<td>Upper Neck Diff.</td>
<td>0.129</td>
<td>14</td>
<td>1.0</td>
<td>17</td>
<td>1.0</td>
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</table>

### BMD, Young-Adult, Age-Matched

<table>
<thead>
<tr>
<th>Region</th>
<th>BMD (g/cm²)</th>
<th>Young-Adult (%)</th>
<th>Age-Matched (%)</th>
<th>BMC (g)</th>
<th>Area (cm²)</th>
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<tbody>
<tr>
<td>Troch Left</td>
<td>0.830</td>
<td>89</td>
<td>-0.9</td>
<td>95</td>
<td>-0.4</td>
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<tr>
<td>Troch Right</td>
<td>0.896</td>
<td>96</td>
<td>-0.3</td>
<td>102</td>
<td>0.2</td>
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<tr>
<td>Troch Mean</td>
<td>0.863</td>
<td>93</td>
<td>-0.6</td>
<td>98</td>
<td>-0.1</td>
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<tr>
<td>Troch Diff.</td>
<td>0.066</td>
<td>7</td>
<td>0.6</td>
<td>8</td>
<td>0.6</td>
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</table>
Common Artifacts That Affect BMD

- Internal artifacts
- External artifacts
- Serendipitous findings – obligation to report?
- Implications for VFA
Position of the Panniculus

2003

Single energy

2012

Single energy

67", 260 pounds

<table>
<thead>
<tr>
<th>Region</th>
<th>Area (cm²)</th>
<th>BMC (g)</th>
<th>BMD (g/cm²)</th>
<th>T-score</th>
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<tbody>
<tr>
<td>Neck</td>
<td>5.36</td>
<td>4.24</td>
<td>0.790</td>
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<td>Total</td>
<td>36.88</td>
<td>36.41</td>
<td>0.987</td>
<td>0.4</td>
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<table>
<thead>
<tr>
<th>Region</th>
<th>Area (cm²)</th>
<th>BMC (g)</th>
<th>BMD (g/cm²)</th>
<th>T-score</th>
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<tr>
<td>Neck</td>
<td>5.35</td>
<td>4.24</td>
<td>0.793</td>
<td>-0.5</td>
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<tr>
<td>Total</td>
<td>37.41</td>
<td>36.79</td>
<td>0.984</td>
<td>0.3</td>
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Position of the Panniculus

2003

Single energy

2012

Single energy

67”, 260 pounds
Surgical Hardware

- Vertebral levels that include an artifact should be excluded.
- ISCD recommends a minimum of 2 vertebra for diagnosis and monitoring.
- They don’t need to be contiguous.
- This spine is not diagnostic, and an alternative site should be measured.
Which analysis is more correct?
Analysis and Reporting Issues
Insufficient Anatomy
Insufficient Anatomy

Not scanning down far enough in the hip is a common error on GE Healthcare scan.
Dear Dr. John

Your patient James completed a BMD test at our facility.

**Patient:**
- **Name:** James
- **Patient ID:**
- **Date of Birth:** 06/05/1921
- **Gender:** Male
- **Indications:** None
- **Fractures:** None
- **Treatments:** None

**Results:**
- **Scan Type**
  - AP Spine: L2-L4
  - Dual Femur: Total Mean
- **Measured:**
  - 10/08/2003

**Assessment:**
- World Health Organization - Definition of Osteoporosis
- Normal: T-Score at or above -1.0
- Osteopenia: T-Score between -1 and -2.5 SD
- Osteoporosis: T-Score at or below -2.5 SD

**Region**
- **L2-L4:** Measured: 10/08/2003, Age: 82.3, BMD: 995 mg/cm², T-Score: -1.6
- **Total Mean:** Measured: 10/08/2003, Age: 82.3, BMD: 957 mg/cm², T-Score: -0.6
Look for discordance in T-scores

<table>
<thead>
<tr>
<th>Region</th>
<th>BMD</th>
<th>T-score</th>
<th>Z-score</th>
</tr>
</thead>
<tbody>
<tr>
<td>L1</td>
<td>0.729</td>
<td>-3.6</td>
<td>-3.0</td>
</tr>
<tr>
<td>L2</td>
<td>0.897</td>
<td>-2.9</td>
<td>-2.3</td>
</tr>
<tr>
<td>L3</td>
<td>0.999</td>
<td>-2.0</td>
<td>-1.5</td>
</tr>
<tr>
<td>L4</td>
<td>1.188</td>
<td>-0.4</td>
<td>+0.1</td>
</tr>
<tr>
<td>L2-L4</td>
<td>1.045</td>
<td>-1.6</td>
<td>-1.1</td>
</tr>
<tr>
<td>L1-L3</td>
<td>0.871</td>
<td>-2.8</td>
<td>-2.3</td>
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</table>
Look for discordance between hips
Specific Disease States
What is the diagnosis?
What is this diagnosis?

Answer: Osteopoikilosis

A core needle bone biopsy of the pelvis was performed. Hemato-pathology report of bone marrow revealed no evidence for metastatic cancer, plasma cell dysplasia or features suggestive of Paget's disease.

The bone sample revealed sclerotic bone within the bone marrow suggestive of osteopoikilosis.

What is your diagnosis?

Lumbar Spine AP Lat L5-S1 with Obliques

Findings/Conclusion: Pagetoid appearance of the L3 and L4 vertebral bodies. Advanced joint space height loss at L1-L2, L4-L5 and L5-S1. No acute compression deformity.

VFA Imaging in suspected compression fx’s

<table>
<thead>
<tr>
<th>Region</th>
<th>Area (cm²)</th>
<th>BMC (g)</th>
<th>BMD (g/cm²)</th>
<th>T-score</th>
</tr>
</thead>
<tbody>
<tr>
<td>L1</td>
<td>14.54</td>
<td>13.13</td>
<td>0.904</td>
<td>-0.9</td>
</tr>
<tr>
<td>L2</td>
<td>14.12</td>
<td>18.25</td>
<td>1.293</td>
<td>1.8</td>
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<tr>
<td>L3</td>
<td>14.65</td>
<td>17.42</td>
<td>1.189</td>
<td>0.8</td>
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<tr>
<td>L4</td>
<td>17.46</td>
<td>18.17</td>
<td>1.041</td>
<td>-0.9</td>
</tr>
<tr>
<td>Total</td>
<td>60.76</td>
<td>66.97</td>
<td>1.102</td>
<td>0.1</td>
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<table>
<thead>
<tr>
<th>Region</th>
<th>Area (cm²)</th>
<th>BMC (g)</th>
<th>BMD (g/cm²)</th>
<th>T-score</th>
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<tbody>
<tr>
<td>L1</td>
<td>11.53</td>
<td>9.40</td>
<td>0.816</td>
<td>-1.6</td>
</tr>
<tr>
<td>L2</td>
<td>12.47</td>
<td>11.28</td>
<td>0.985</td>
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<tr>
<td>L3</td>
<td>12.64</td>
<td>12.45</td>
<td>0.985</td>
<td>-0.9</td>
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<tr>
<td>L4</td>
<td>12.96</td>
<td>10.48</td>
<td>0.808</td>
<td>-2.3</td>
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<tr>
<td>L1-L2</td>
<td>24.00</td>
<td>20.69</td>
<td>0.862</td>
<td>-1.1</td>
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</table>
What is your diagnosis?

Sickle Cell Disease

<table>
<thead>
<tr>
<th>Region</th>
<th>Area (cm²)</th>
<th>BMC (g)</th>
<th>BMD (g/cm²)</th>
<th>T-score</th>
<th>PR (%)</th>
<th>Z-score</th>
<th>AM (%)</th>
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<tr>
<td>L1</td>
<td>12.95</td>
<td>20.75</td>
<td>1.602</td>
<td>4.8</td>
<td>149</td>
<td>3.9</td>
<td>137</td>
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<td>L2</td>
<td>13.74</td>
<td>21.63</td>
<td>1.575</td>
<td>4.4</td>
<td>144</td>
<td>3.4</td>
<td>131</td>
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<tr>
<td>L3</td>
<td>14.02</td>
<td>21.86</td>
<td>1.559</td>
<td>4.1</td>
<td>141</td>
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<tr>
<td>L4</td>
<td>15.98</td>
<td>25.32</td>
<td>1.584</td>
<td>4.5</td>
<td>145</td>
<td>3.5</td>
<td>132</td>
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<td>Total</td>
<td>56.69</td>
<td>89.56</td>
<td>1.580</td>
<td>4.4</td>
<td>145</td>
<td>3.5</td>
<td>132</td>
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Where is it?
What is it?
Visual Challenge

Practicing visual identification of common hip and spine artifacts
Where is it?  What is it?
Where is it? What is it?
Where is it?  What is it?
Where is it?  What is it?
Where is it?  What is it?
Where is it?  What is it?
Partial sacralization of L5 with sclerotic articulation
Where is it? What is it?
Where is it? What is it?
Where is it?  What is it?
Where is it?  What is it?
DXA Quality Matters!!
Look At The Images!
“You can observe a lot just by watching.”

- Yogi Berra