Pediatric DXA: Performance, interpretation, and challenges

Adina Alazraki, MD, FAAP
Assistant Professor, Radiology and Pediatrics
Emory University School of Medicine
Children’s Healthcare of Atlanta
Challenges

Technical:
- Patient positioning
- Performance of the scan
- Analysis of the data

Theoretical:
- Identification of a suitable control population
- Interpretation of ‘normal’ for growing skeleton
DXA indications

- Systemic long-term steroids
- Chronic inflammatory conditions
- Hypogonadism
- Prolonged immobilization
- Osteogenesis imperfecta
- Idiopathic juvenile osteoporosis
- Recurrent low trauma fractures
- Apparent osteopenia on radiographs

<table>
<thead>
<tr>
<th>Table 1 Diseases considered by the Position Development Conference (PDC) as potentially affecting the skeleton and associated with an increased fracture risk in children and adolescents</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diseases that potentially affect the skeleton</td>
</tr>
<tr>
<td>Primary Bone Disorders</td>
</tr>
<tr>
<td>Idiopathic juvenile osteoporosis (IJO)</td>
</tr>
<tr>
<td>Osteogenesis imperfecta (OI)</td>
</tr>
<tr>
<td>Secondary Bone Disorders</td>
</tr>
<tr>
<td>Inflammatory diseases</td>
</tr>
<tr>
<td>Inflammatory bowel disease (IBD)</td>
</tr>
<tr>
<td>Juvenile idiopathic arthritis (JIA)</td>
</tr>
<tr>
<td>Cystic fibrosis (CF)</td>
</tr>
<tr>
<td>Chronic immobilization</td>
</tr>
<tr>
<td>Cerebral palsy (CP)</td>
</tr>
<tr>
<td>Myopathic disease</td>
</tr>
<tr>
<td>Epidermolysis bullosa (EB)</td>
</tr>
<tr>
<td>Endocrine disturbances</td>
</tr>
<tr>
<td>Turner syndrome (TS)</td>
</tr>
<tr>
<td>Anorexia nervosa (AN)</td>
</tr>
<tr>
<td>Cancer and therapies with adverse effects on bone health</td>
</tr>
<tr>
<td>Acute lymphocytic leukemia (ALL) and following chemotherapy for childhood cancer</td>
</tr>
<tr>
<td>Transplant bone disease</td>
</tr>
<tr>
<td>Hematologic disorders</td>
</tr>
<tr>
<td>Thalassemia</td>
</tr>
</tbody>
</table>

Special considerations apply to some of these conditions. For example, TS does not have an increased risk of fractures in childhood but only later. In other disorders, multiple factors, such as low physical activity, the effect of drugs, and/or disease-dependent metabolic alterations, are likely to contribute to the increase in bone fragility. The categorization presented does not reflect the complexity of these problems.
Technique

- Relies on the absorption of x-rays of 2 different energy levels
  - Low energy: 30-50 keV - bone attenuation > soft tissue
  - High energy: >70 keV - bone is similar to soft tissue
- Quantification in grams
"The diagnosis of osteoporosis in children and adolescents should NOT be made on the basis of densitometric criteria alone.

Osteoporosis requires both a ‘clinically significant fracture history’ and low bone mineral content or bone mineral density.

Clinically significant fracture history is one or more of the following:

- long bone fracture of the lower extremities
- vertebral compression fracture
- two or more long–bone fractures of the upper extremities

Low bone mineral content or bone mineral density = BMC or areal BMD Z-score < or = −2.0, adjusted for age, gender and body size, as appropriate
Nomenclature

- More specific terminology
- Perhaps ‘pet peaves’

Appendix 3

Nomenclature

DXA not DEXA

Z-score not Z score, z–score, or z score

DXA decimal digits

Preferred number of decimal digits for DXA reporting:

BMD (e.g. 0.927 g/cm²) 3 digits

Z-score (e.g. 1.7) 1 digit

BMC (e.g. 31.76 g) 2 digits

Area (e.g. 43.25 cm²) 2 digits

Percentage reference database (e.g. 82%) integer
DXA

- DXA is an *areal* rather than a *volumetric* density measurement.
- DXA-derived BMD is based on the two-dimensional projected area of a three-dimensional structure.
- The third dimension, depth cannot be accounted for because it is in the same direction as the xray beam.
- Results in inherent error.
- PA lumbar spine and TBLH are most accurate and reproducible
- Soft tissue measures may help in systemic diseases
- Hip is not reliable during growth
DXA Performance

- Positioning and ROI selection
  - Lumbar spine: straight and centered; last rib pair and upper sacrum visualized
  - Whole body
- ROIs are generated automatically using edge-detection software for L1 to L4
- Artifact can falsely elevate aBMD
- BMC not affected by artifact
- Small child
- Very low bone mineral density (OI)
- Makes for difficult anatomic delineation
- Posterior spinal fusion hardware makes accuracy difficult
- Attempt to mask the hardware has limited value
- Trend may be more helpful as long as masking is similar
Interpretation: adults vs children

- Z-score of zero is equivalent to the mean
- T-score is a measure of bone density loss since early adulthood—NA to peds
- It is recommended that the phrase “low bone density” be used in DXA reports
- Age, gender, ethnicity, and physiologic maturity level are included in most current normative datasets

Baseline DXA reports should contain the following information:

- DXA manufacturer, model and software version
- Referring physician
- Patient age, gender, race/ethnicity, weight, and height
- Relevant medical history including previous fractures
- Indication for study
- Bone age results, if available
- Technical quality
- BMC and areal BMD
- BMC and areal BMD Z-score
- Source of reference data for Z-score calculations
- Adjustments made for growth and maturation
- Interpretation
- Recommendations for the necessity and timing of the next DXA study are optional
What do we report?

- Total body less head BMD
- Body composition data:
  - Total BMC
  - Lean body mass
  - Fat mass/fat percentage
  - Height-for-age
- AP spine BMD
ANCILLARY RESULTS [Total Body]

<table>
<thead>
<tr>
<th>Region</th>
<th>BMI (kg/m²)</th>
<th>Young Adult (cm)</th>
<th>Age-Matched (cm)</th>
<th>BMC (g)</th>
<th>Area (cm²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Head</td>
<td>1.661</td>
<td>-</td>
<td>-</td>
<td>365.5</td>
<td>220</td>
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<tr>
<td>Left Arm</td>
<td>0.697</td>
<td>-</td>
<td>-</td>
<td>308.3</td>
<td>132</td>
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<tr>
<td>Left Leg</td>
<td>1.056</td>
<td>-</td>
<td>-</td>
<td>250.2</td>
<td>332</td>
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<tr>
<td>Left Trunk</td>
<td>0.772</td>
<td>-</td>
<td>-</td>
<td>311.9</td>
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<tr>
<td>Left Total</td>
<td>0.968</td>
<td>-</td>
<td>-</td>
<td>826.9</td>
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<td>Right Arm</td>
<td>0.853</td>
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<td>-</td>
<td>153.0</td>
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<td>Right Leg</td>
<td>1.210</td>
<td>-</td>
<td>-</td>
<td>369.7</td>
<td>361</td>
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<tr>
<td>Right Trunk</td>
<td>0.781</td>
<td>-</td>
<td>-</td>
<td>234.6</td>
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<td>Right Total</td>
<td>1.011</td>
<td>-</td>
<td>-</td>
<td>1314.0</td>
<td>1030</td>
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<tr>
<td>Arms</td>
<td>0.655</td>
<td>-</td>
<td>-</td>
<td>221.6</td>
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<td>Legs</td>
<td>1.044</td>
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<td>735.0</td>
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<td>Trunk</td>
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<td>Ribs</td>
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<td>Pelvis</td>
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<td>Spine</td>
<td>0.909</td>
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<td>-</td>
<td>238.0</td>
<td>229</td>
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<tr>
<td>Total</td>
<td>0.991</td>
<td>92</td>
<td>-1.4</td>
<td>1967.4</td>
<td>1997</td>
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<tr>
<td>Total (Head)</td>
<td>0.907</td>
<td>-</td>
<td>-</td>
<td>1132.4</td>
<td>1757</td>
</tr>
</tbody>
</table>

Pediatric Information:
- Statistical T95% of normal values fall within 1SD (± 0.010 g/cm² for Total Body Total)
- Body Mass (kg) ± 0.010 g/cm² for Total Body Total
- Matched for Age, Ethnic
- Technique used (not specified)
- PHU: Pediatric Healthy Utility
- Scan Mode: Standard 0.4 cm²

*Height for Age*:

*Bone Area for Height*:

*Bone Area for BMC*:

Image not for diagnosis.
Serial DXA reports should include the same information as for baseline testing, but additionally include:

- indications for follow-up scan
- comparability of studies
- interval changes in height, weight
- BMC and areal BMD Z-scores adjusted or unadjusted for height or other adjustments
- percentage change in BMC and areal BMD and interval change in Z-scores
- recommendations for the necessity and timing of the next BMD study are optional.
Reporting the trend

“TOTAL BODY LESS HEAD: Bone mineral density is 0.816 g/cm². This is 81 percent of age-matched controls and yields a Z score of -2.3. There has been 9% improvement from the previous.”
Summary

- Must have accurate patient info (age, height, wt, sex, ethnicity)
- Use appropriate control reference data
- Pay attention to terminology
- Z-score not T-score
- Make sure the clinicians who refer know the capabilities of your software