Published in final edited form as:

Acad Radiol. 2011 June ; 18(6): 722–725. doi:10.1016/j.acra.2011.01.009.

Determination of Osteopenia in Children on Digital Radiography Compared with a DEXA Reference Standard

Philipose G Mulugeta, BA*,

Vanderbilt School of Medicine, Box 69, 201 Light Hall, Vanderbilt University, Nashville, TN 37232

Martin Jordanov, M.D.,

Department of Radiology, Vanderbilt School of Medicine, CCC-1121 MCN, Vanderbilt University, Nashville, TN 37232-2675

Marta Hernanz-Schulman, M.D.,

Department of Radiology, Vanderbilt School of Medicine, 423 VCH, Vanderbilt University, Nashville, TN 37232-9700

Chang Yu, PhD, and

Department of Biostatistics, Vanderbilt Clinical Research Center, S-2323 MCN, Vanderbilt University, Nashville, TN 37232-2195

J Herman Kan, M.D.

Department of Radiology, Vanderbilt School of Medicine, 2200 Children's Way, Ste. 1419, Vanderbilt University, Nashville, TN 37232-9700

Abstract

Rationale and Objectives—The aim of this study was to explore the reliability of osteopenia diagnosis based on digital radiographs of appendicular skeleton obtained as part of routine clinical practice as compared with DEXA (Dual energy X-ray absorptiometry) gold standard (Z-score < -1).

Materials and Methods—The study was an IRB-approved retrospective study of 58 children (mean age 12 years [4–18]). Digital radiographs of appendicular skeleton obtained within 6 months of DEXA scanning were presented in a blinded fashion to two musculoskeletal radiologists who were instructed to grade the level of mineralization. Sensitivity and specificity of each reviewer's osteopenia grading were calculated in comparison to lumbar DEXA Z-score values. Interobserver agreement was also calculated and significance evaluated with Bowker's test.

Results—The reviewers correctly identified 28% of all patients with severe osteopenia (Z-score ≤ -2.0) as well as 26% of all patients with mild osteopenia ($-2 < \text{Z-score} < -1$). Inter observer agreement for the correct diagnosis of BMD category ranged from 71% for normal BMD (Z-score > -1) to 0 and 25% for mild and severe osteopenia respectively.

Conclusions—Visual diagnosis of osteopenia based on digital radiographs of appendicular skeleton has poor sensitivity and interobserver agreement. Clinical features and risk factors of pediatric patients should therefore guide DEXA evaluation and treatment recommendations.

*Corresponding Author: phmulugeta@gmail.com, phone: 615-829-6547, fax: 928-436-7380.

Publisher's Disclaimer: This is a PDF file of an unedited manuscript that has been accepted for publication. As a service to our customers we are providing this early version of the manuscript. The manuscript will undergo copyediting, typesetting, and review of the resulting proof before it is published in its final citable form. Please note that during the production process errors may be discovered which could affect the content, and all legal disclaimers that apply to the journal pertain.

Keywords

Pediatric osteopenia; osteoporosis; DEXA; digital radiograph

INTRODUCTION

In both adults and children digital radiographs obtained as part of routine clinical practice may be the first modality that raises suspicion for low bone mineral density when increased radiotranslucency of bones is demonstrated. In appendicular bones, objective criteria for the radiographic identification of osteopenia include relative cortical thickness related to overall bone caliber, cortical sharpness, qualitative determination of trabecular rarefaction, and density variations between bone and soft tissue (1). Radiologists will often use both such objective criteria as well as subjective overall image “gestalt” in determining the quality of bone mineral density in appendicular bone.

DEXA is a reliable and accurate method to determine BMD in both adults and children. In the pediatric population, BMD values from DEXA are influenced by puberty, body habitus as well as sex and ethnic differences. DEXA BMD values for children should therefore utilize normative databases and Z-scores to account for demographic variations of bone mass in children (2)(3). Currently some accepted indications for DEXA imaging in children include systemic long-term steroid use (>2 months), chronic inflammatory conditions, hypogonadism, osteogenesis imperfecta and recurrent low trauma fractures(4)(5).

Prior studies have compared visual assessment of osteopenia in the lumbar spine with a DEXA reference standard. In one such study of the lumbar spine analyzing adult patients, radiologists blinded to the patients’ age and DEXA values correctly identified the majority of patients with osteopenia (6). However, diagnostic accuracy and interobserver agreement were lower for digital images than for conventional radiographs. Our purpose is to determine the reliability of osteopenia diagnosis based on digital images of the appendicular skeleton obtained as part of routine clinical practice in children, in comparison to DEXA studies in the same patient population, and compare radiologist interobserver variability for the determination of osteopenia.

METHOD AND MATERIALS

Patient population

This was an IRB-approved retrospective study of 58 consecutive children presenting between 2004–2009. Images of appendicular bone obtained within 6 months of index DEXA study on patients (45% male, mean age of 12 years, range 4–18) were reviewed. Appendicular skeletal images surveyed included: knee (10), forearm (10), femur (9), foot (7), lower leg (7), hand (3), humerus (3), finger (3), ankle (2), wrist (2), and elbow (2)

Image analysis

Two musculoskeletal radiologists blinded to patient clinical information, DEXA results and each other’s conclusions were instructed to grade digital radiographs as normal bone density, mild or severe osteopenia. One radiologist had musculoskeletal fellowship training with 3 years of experience. The second radiologist had both pediatric and pediatric musculoskeletal fellowship training with 5 years of experience.

Statistical analysis

Osteopenia was defined as a Z-score of less than -1 (Z-score < -1). Severe osteopenia was defined as Z-score -2.0 and lower (Z-score ≤ -2.0). Mild osteopenia was defined as a Z score greater than -2 and less than -1 (-2 < Z-score < -1). Normal mineralization was a Z score of -1 and higher (Z-score ≥ -1).

The sensitivity and specificity of each reviewer's visual determination of osteopenia based on inspection of the appendicular skeletal digital images was calculated in comparison with lumbar DEXA Z-score values; interobserver variability was also calculated. Reviewers were adjudged to have correctly diagnosed osteopenia (Z-score < -1) if they assigned a subjective grade of either severe or mild osteopenia to a patient's images. Therefore, sensitivity for any osteopenia (Z-score < -1) does not equal the sum of sensitivity for mild and severe osteopenia for both reviewers.

Proportions of patients classified into the categories (normal, mild, severe) by the various methods were calculated from the data set. The Bowker's test of symmetry was used to compare each reviewer's assessment against the DEXA evaluation. Bowker's test examines the hypothesis of the marginal homogeneity in a two-way classification table. If the test is significant, it means that the methods are selecting the categories in differing proportions. P values less than 0.05 are considered statistically significant. All tests are two-tailed. Statistical analyses are performed using the statistical package SAS for Windows (Version 9, Cary, NC) and Microsoft Excel for Macintosh (Version 12.2.5, Redmond, WA).

RESULTS

Per DEXA value scores, there were 16 patients with severe osteopenia, 8 patients with mild osteopenia, and 34 patients with normal mineralization.

Reviewer 1 (Table 1), correctly identified 31% of all patients with severe osteopenia (Z-score ≤ -2.0), 13% of all patients with mild osteopenia (-2 < Z-score < -1) as well as 50% of all patients with any osteopenia (Z-score < -1). Reviewer 1 correctly identified patients with normal bone density (Z-score ≥ -1) 82% of the time. For Reviewer 1, sensitivity and specificity for the identification of any osteopenia were 50% and 82%, respectively.

Reviewer 2 (Table 2), correctly identified 25% of all patients with severe osteopenia (Z-score ≤ -2.0), 38% of all patients with mild osteopenia (-2 < Z-score < -1) as well as 67% of all patients with any osteopenia (Z-score < -1). Reviewer 2 correctly identified patients with normal bone density (Z-score ≥ -1) 76% of the time. For Reviewer 2, sensitivity and specificity for the identification of any osteopenia were 67% and 76%, respectively.

Interobserver agreement between the two readers for the correct diagnosis of normal bone mineralization was 71%, but this decreased with abnormal findings, 25% for severe osteopenia, and 0% for mild osteopenia. Independent of correct diagnosis by correlation with DEXA Z-score values, reviewer 1 and reviewer 2 agreed in 75% of normal, 60% of mild and 63% of severe osteopenia diagnoses (Table 3).

Discussion

To date, the accuracy and reliability of visual diagnosis of osteopenia on digital radiography of appendicular skeleton is poorly studied in the pediatric population, although the reliability of determining osteopenia with the use of digital radiographs of axial skeleton has been previously investigated. The study by Wagner *et al.* in adult patients showed 80% sensitivity and 36% specificity in determining osteopenia on conventional radiographs of the adult

lumbar spine, but their sensitivity decreased to 65% on digital radiographs, with a concurrent decrease in interobserver agreement from 73% on conventional radiographs to 35% on digital images (6).

Our findings concur with the poorer performance when evaluating digital images, and suggest that radiologist reliability in determination of bone mineralization of the appendicular skeleton in children based on digital imaging is poor; this could be secondary to changes effected by post-processing which may potentially confound our ability to apply the usual objective and subjective criteria to our image analysis based on past experience with non-digital radiographs. However, we also found that with increasing severity of BMD loss, the reliability of diagnosis improves, as the proportion of patients that were diagnosed with some form of osteopenia also increases for both reviewers (figures 1 and 2).

There are some limitations to our study. First, the total number of patients who qualified for inclusion in our study (58) as well as the low number of patients in the mild osteoporosis category limits the scope of our findings. Two, DEXA determination of bone mineral density was in the lumbar spine, which is in a different location than the appendicular skeletal radiographs that were analyzed by the radiologists. Therefore, it is possible that bone mineral density based on lumbar spine values may not be applicable to the appendicular skeleton, thereby affecting both sensitivity and specificity calculations for both radiologists.

In conclusion, our findings indicate that, although determination of normal bone mineralization is adequate, the visual diagnosis of osteopenia/osteoporosis based on digital radiographs of appendicular skeleton has low sensitivity in the pediatric population, with poor interobserver agreement when correlated with DEXA reference diagnosis. Visual diagnosis of osteopenia based on digital radiography of the appendicular skeleton in children is not sufficiently reliable to guide or modify clinical management, and further diagnostic testing based on patients' clinical risk factors is indicated. Therefore, radiologists should exercise caution with regard to discussing bone mineralization in pediatric appendicular skeleton radiographs.

Acknowledgments

Grant support: Statistical support funded in part by the Vanderbilt CTSA grant UL1 RR024975 from NCRR/NIH.

References

1. Brant, WE.; Helms, CA. Fundamentals of Diagnostic Radiology. Philadelphia, Pa: Lippincott Williams & Wilkins; 2007.
2. Gordon CM, Bachrach LK, Carpenter TO, Crabtree N, El-Hajj Fuleihan G, Kutilek S, et al. Dual energy X-ray absorptiometry interpretation and reporting in children and adolescents: the 2007 ISCD Pediatric Official Positions. J Clin Densitom. 2008; 11:43–58. [PubMed: 18442752]
3. Diagnosis of osteoporosis in men, premenopausal women, and children. J Clin Densitom. 2004; 7:17–26. [PubMed: 14742884]
4. Binkovitz LA, Henwood MJ. Pediatric DXA: technique and interpretation. Pediatr Radiol. 2007; 37:21–31. [PubMed: 16715219]
5. Steelman J, Zeitler P. Osteoporosis in Pediatrics. Pediatrics in Review. 2001; 22:56–65. [PubMed: 11157102]
6. Wagner S, Stabler A, Sittek H, Bonel H, Laeverenz G, Reiser MF, et al. Diagnosis of osteoporosis: visual assessment on conventional versus digital radiographs. Osteoporos Int. 2005; 16:1815–22. [PubMed: 15981020]

Figure 1.

Percentage of patients diagnosed as normal BMD or low bone mineral density in different Z-score categories (Normal = Z-score ≥ -1 , Mild = $-2 < \text{Z-score} < -1$, Severe = Z-score ≤ -2.0) by reviewer 1. A designation of mild or severe osteopenia by reviewer within each Z-score category is recorded as any osteopenia. For instance, in the “normal” BMD column, 18% of patients with normal bone mineralization were incorrectly identified to have osteopenia and 82% were correctly identified as having normal bone mineralization. In the mild osteopenia BMD column, 38% of patients with mild osteopenia were correctly identified as osteopenic while , but 62% were incorrectly identified as having normal bone mineralization

Figure 2.

Percentage of patients diagnosed as normal BMD or low bone mineral density in different Z-score categories (Normal = Z-score ≥ -1 , Mild = $-2 < \text{Z-score} < -1$, Severe = Z-score ≤ -2.0) by reviewer 2. A designation of mild or severe osteopenia by reviewer within each Z-score category is recorded as any osteopenia. For instance, in the “normal” BMD column, 24% of patients with normal bone mineralization were incorrectly identified to have osteopenia and 76% were correctly identified as having normal bone mineralization. In the mild osteopenia BMD column, 63% of patients with mild osteopenia were correctly identified as osteopenic while 37% were incorrectly identified as having normal bone mineralization.

Table 1

Reviewer 1 (R1) visual rating of osteopenia as compared to DEXA determination of bone mineral. The Bowker's P-value for R1 is not significant (0.16) indicating that radiologist is selecting the categories in similar proportions as the DEXA standard. Shaded cells represent agreement between R1 and DEXA bone density categories.

	Reviewer 1			
		Normal	Mild	Severe
DEXA	Normal	82%	15%	3%
	Mild	62%	13%	25%
	Severe	43%	25%	31%

Table 2

Reviewer 2 (R2) visual rating of osteopenia as compared to DEXA determination of bone mineral density. The Bowker's P-value for R2 is significant (0.018) indicating that radiologist is selecting the categories in differing proportions as the DEXA standard. Shaded cells represent agreement between R2 and DEXA bone density categories.

	Reviewer 2			
		Normal	Mild	Severe
DEXA	Normal	76%	24%	0%
	Mild	37.5%	37.5%	25%
	Severe	31%	43%	25%

Table 3

Reviewer 1 (R1) vs. Reviewer 2 (R2) interobserver agreement by DEXA determined bone mineral density categories. Percentage agreement is calculated based on R1's totals in each BMD category and is not correlated to DEXA standard. The Bowker's P-value for interobserver agreement is not significant (0.1154) indicating that both radiologists are selecting categories in similar proportions. Shaded cells represent agreement between R1 and R2 visual bone density categories without correlation with DEXA standard.

	Reviewer 2			
		Normal	Mild	Severe
Reviewer 1	Normal	75%	22.5%	2.5%
	Mild	40%	60%	0%
	Severe	0%	37.5%	62.5%