Graphic Representation of Skeletal Maturity Determinations

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OBJECTIVE. Skeletal maturation determinations are usually reported as numeric data indicating accordance with chronologic age. However, significant changes in skeletal maturation can occur without falling outside two SDs. The purpose of our study was to design simple computer-generated sex-based charts to enhance the evaluation of skeletal maturation, especially when frequent assessments are made.

CONCLUSION. The graphic representation of successive reports clearly depicts whether values retain their position in relation to the mean. In addition, the report includes computation of the exact SD score.

Bone age assessment is frequently performed in children and adolescents for the evaluation of growth and the diagnosis and management of a multitude of endocrine disorders and pediatric syndromes. A single interpretation of skeletal age informs the clinician of the relative maturity of a patient's skeleton at a particular time and, integrated with other clinical findings, separates normal skeletal maturation from relatively advanced or delayed skeletal maturation. Successive skeletal age interpretations indicate the direction of the child's development and show the progress under treatment. In healthy subjects, bone age should fall roughly within two SDs of reference norms, which are most commonly based on the Greulich and Pyle atlas [1].

In contrast to other key anthropometric measurements, which are usually documented on growth charts, bone age is reported in simple numeric form using SD scores without any graphic representation. However, this reporting format may limit our ability to discern the direction of a child's development and to show the progress of abnormal skeletal maturation. For example, a 13-year-old boy with short stature underwent three bone age determinations during the previous 28 months, which were all reported as "…within two SDs for his chronological age," despite a progressive decline in skeletal maturity as a consequence of the development of hypothyroidism resulting from a deficient and ectopic thyroid gland (Fig. 1). This clinical case encouraged us to design a simple computer-generated chart to facilitate the evaluation of a child's skeletal maturity.

Materials and Methods

A bone age graphical user interface was designed and programmed as a stand-alone application using MATLAB R2006a (The MathWorks). Because the normal rate of skeletal maturity differs between males and females, charts were developed based on sex (Figs. 1 and 2). The program outputs the data to a graphic in which the *x*-axis is chronologic age and the *y*-axis is bone age. In addition, the user can enter multiple data points so that a child's progression over time can be mapped out and visualized (Fig. 1).

Means and SDs for bone age were obtained from the norms generated by Harold C. Stuart of the Department of Maternal and Child Health of the Harvard School of Public Health in Boston, Massachusetts, as indicated in tables 5 and 6 of the Greulich and Pyle *Radiographic Atlas of Skeletal Development of the Hand and Wrist* [1]. The underlying equation for calculating the SD of a child's bone age from the expected bone age is

$$SD = \frac{BA - CA}{SDBA}$$

In this formula, *BA* is the subject's bone age in months, *CA* is the subject's chronologic age in months, and *SDBA* is the SD of *BA* as reported by Stuart. The program will accept bone ages and chronologic ages between integers and calculate the weighted SD accordingly.

Keywords: bone age, graphic representation, skeletal maturation

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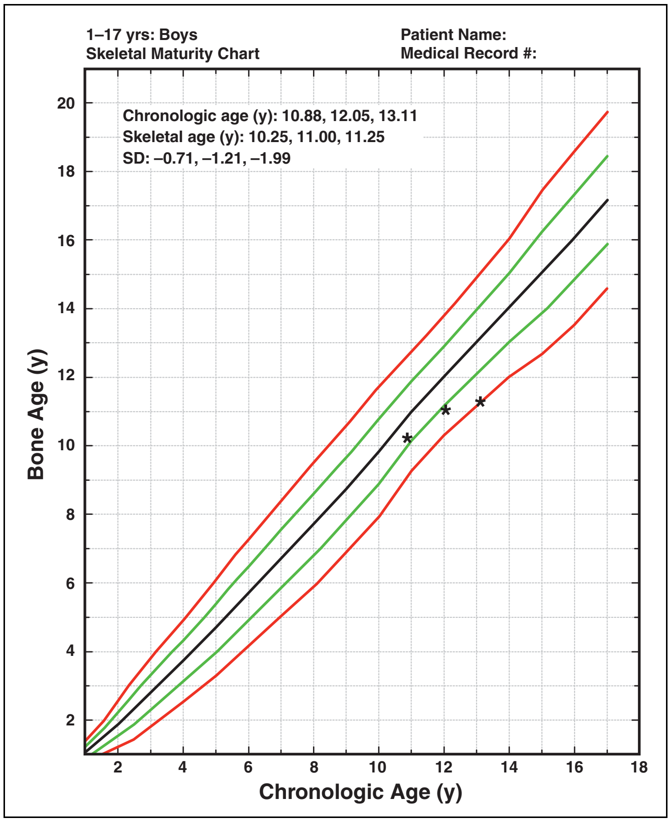

Fig. 1—Skeletal maturity chart for boys comparing bone age and chronologic age, including computation of three SD scores (*asterisks*), shows progressively delayed skeletal maturation. Black line = mean value, green lines = one SD, red lines = 2 SD.

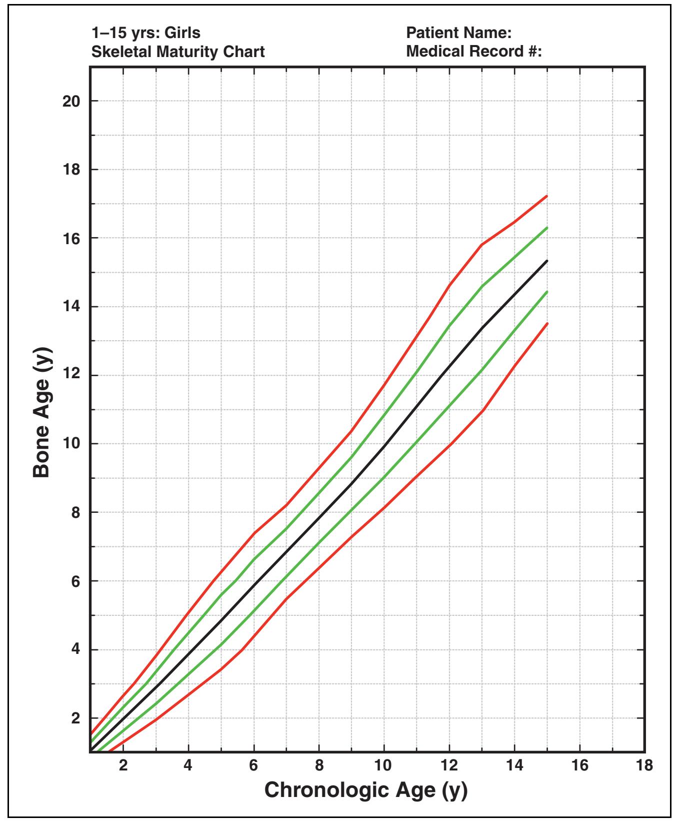

Fig. 2—Skeletal maturity chart for girls compares bone age and chronologic age. Black line = mean value, green lines = one SD, red lines = 2 SD.

Discussion

The evaluation of a child's skeletal maturity is generally reported in the context of numeric data indicating the difference in SD scores between the patient's bone age and chronologic age. When chronologic and skeletal ages concur, the radiologist frequently reports the bone age to be in accordance with or within one or two SDs of the chronologic age. However, significant changes in skeletal maturation can occur without falling outside two SDs.

The simple computer-generated chart described herein will enhance the information and facilitate the evaluation of skeletal maturation determinations. The graphic representation of successive reports clearly depicts whether values retain their position in relation to the mean (Fig. 1). In addition, the report includes computation of exact SD scores rather than the range in which they lie. When values do not track and cross the SD, radiologists will be encouraged to reassess previous interpretations before finalizing their reports.

Bone age reports, like those for height, weight, and body mass index, would benefit from a graphic representation. A limitation of these bone age charts is that the SD scores were derived from the Greulich and Pyle atlas [1], which was based on a study by T. Wingate Todd of a limited group of subjects who were primarily white, middle-class children from northeastern Ohio. In contrast, the Centers for Disease Control and Prevention provided comprehensive growth charts relative to the third or fifth, 10th, 25th, 50th, 75th, 90th, and 95th or 97th percentiles based on a large cohort of normal children representing the population of the United States [2]. This limitation, however, applies to all interpretations conducted according to the method of Greulich and Pyle, regardless of whether they are or are not represented graphically.

Several automated methods to facilitate the analysis of skeletal maturity are currently available [3, 4]. However, regardless of the method used, bone age determinations are reported in the context of numeric data indicating the difference in SD scores between the patient's bone age and chronologic age. We developed a simple automated method to graphically represent the bone ages of children to enhance the information and facilitate the evaluation of skeletal maturation determinations, especially when frequent assessments are made. Since January 2007, bone age charts generated by this program have been digitally integrated into the Patient Centric Information Management System (PCIMS) of the UCLA Healthcare and are part of the permanent medical records of our patients.

References

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