Annotations

How to make the most of bone ages

Bone age estimations used correctly are a valuable adjunct in clinical paediatrics. Many paediatricians do not, however, recognise that reported bone age values may be inappropriately estimated and inaccurate. It is natural to accept without question the typed report of a radiologist, as one would other laboratory pathological results, and to use this information uncritically. Yet such reports may not only be inaccurate but positively misleading, and a clinical judgment would be better without them.

Factors that influence results of bone age estimations

The degree of accuracy required in bone age estimation varies with circumstances. Single estimations for aid in diagnosis do not require great accuracy (for example, accuracy to half a year would be satisfactory) but serial observations to show changes over periods of time demand considerable accuracy best achieved by the same interpreter.

There is a marked sex difference in bony development. Girls throughout the whole of childhood have notably advanced bone ages compared with boys, and so, of course, it is essential to use the correct sex standards in reference.¹

In attributing an age to the state of individual bony development, the bones must be compared with standards that have been developed from examination of radiographs of many supposedly normal individuals of a particular population at a particular time. In practice, patient's radiographs are often not compared with the correct standards.

Standards have mostly been developed from cross sectional studies of many individuals x-rayed once. The pattern of change of an individual as his age increases does not, however, change precisely as cross sectional standards would suggest. At puberty, in parallel with the growth spurt in height, so is there normally a spurt in advancement of bone age. This increased velocity may easily be misinterpreted as an indication of abnormality if puberty is not recognised to be the cause.

Methods of estimating bone age

Most methods in current use depend on the radiological appearances of the bones of the left wrist and hand. It is customary to use the left side, not because there is usually any significant difference in bony

development on the two sides, but because it ensures greater consistency in serial observations.

(1) Method of Pyle et al.² This compares the test radiograph with a series of standard radiographs to which a particular bone age has been attributed. The method is quick and relatively simple but has serious limitations. It was developed from an American population and is not appropriate for populations of other countries such as Britain. For most of the age range there is only one illustration per year of age, so the level of possible accuracy is very limited. Frequently the test radiograph does not match up well with any of the standards, as the bones may not all develop at rates parallel to those of the standards.

(2) Methods of Tanner and Whitehouse. The original method (TW1)³ was revised and superseded in 1975 by the TW2.⁴ These systems depend on scoring the stage of bony development of each of 20 bones of the wrist and hand by comparison with a series of scored standards. These values are totalled to give a skeletal score for which a skeletal age may be read directly from tables. The 20 bone total has been separated into two component estimates, one based on 7 carpal bones (TW carpal) and the other on 13 epiphyses of the radius, ulna, and long bones of the hand (TW RUS). These two components show their more dramatic changes at different stages of growth of the child and so may be more appropriate at these times, avoiding the necessity of the full 20 bone estimations. This system is more laborious and time consuming than that of Pyle *et al.* but is much more reliable and accurate. It requires considerable experience, however, and even trained observers may differ in their interpretations. Correct radiographic technique is essential, for incorrect positioning of the hand may alter greatly the appearance of the bones. At some stages of bony development relatively small changes in the appearance of bones may be responsible for large increases in skeletal score, and so even this method is limited in its accuracy. The system is based on British children's standards and is therefore appropriate for a British and probably for a European population.

Evaluation of the bone ages of the hands shown in the atlas of Pyle *et al.* by the method and standards of TW2 shows an appreciable difference at all ages from the originally designated values⁵—the American standards giving results one to two years more advanced than the British ones. Such a difference is so large as to render the American method of little or no value to a British population.

(3) Method of de Roo and Schroder.⁶ This recently published Dutch atlas is based on illustrations similar to Pyle *et al.*, is more appropriate than the latter for a European population, but has the same limitation in accuracy.

(4) Line illustrations.¹ These provide a quick approximation for comparison of test radiographs and the illustrations are based on up to date values for British children.

Uses of bone age estimations

In determining physiological age, growth potential, and prediction of adult stature. There is a great range in the values of accurately determined bone ages for normal healthy children at any particular chronological age. This may be shown by centiles of skeletal age and scores.⁴ This range is an indication of the variation of physiological development that children acquire—the so called ‘physiological age’—from which deviation from chronological age becomes clinically apparent only at the age when pubertal changes manifest themselves. The degree to which bone age is retarded or advanced in a child is an indication of increased or reduced growth potential in that individual, compared with the average. The bone age is thus of great importance in methods of predicting ultimate adult stature.

In diagnosis. Many childhood diseases and disorders, particularly those causing growth problems, show characteristic relations between bone age and chronological age. The bone age is thus a useful element in confirming a diagnosis. Hormonal deficiencies, notably those of thyroid and growth hormone, usually cause the most severe degrees of bone age retardation (for example, 3 or more years) but depend, of course, on the duration of the deficiency, and there may be greater disparities with increasing age of the untreated child. Most chronic disorders that impair growth as the consequence of metabolic causes or undernutrition will, however, also result in a variable degree of retardation of bone age (for example, by two years or so). In contrast, conditions that accelerate growth such as thyrotoxicosis, sexual precocity, and to a lesser

extent simple exogenous obesity, advance bone age. It is not possible, however, to be dogmatic about where the borderline lies between a notable physiological variation and one that is pathological, and judgment depends on the overall clinical picture. If the deviation in bone age is dependent on a potentially treatable defect, then the growth potential will be indicated better by including a consideration of bone age than by chronological or height age alone.

In monitoring treatment or the course of a disease. Serial observations show how bone ages change with time in comparison with changes in chronological age, height age, etc. These may contribute to the assessment of the appropriateness of treatment, but as indicated previously the normal bone age changes at puberty must not be allowed to confuse the picture and result in erroneous conclusions about the course of the disease or its treatment. Changes in bony appearance appear relatively slowly and it is questionable whether estimates more frequent than once a year are justified or useful.

Prediction of adult height

Many methods have been developed for prediction of adult height^{4 7 8} but in the United Kingdom the most popular and reliable is that of Tanner *et al.* Until recently this depended only on a knowledge of a child's height, bone age, and chronological age (inclusion of parental height factors are not considered to improve the prediction). These standards had largely been based on the growth of normal children whose heights fell within a relatively restricted range on either side of mean stature. In clinical practice, however, it is the very tall or short children for whom a prediction is most often needed, and this previous method was found to have limited reliability in these situations. The latest modification of this method of prediction appears in the current issue of this journal⁹ and seems to have answered the deficiencies of the previous method. It is somewhat more complex involving several alternative tables depending on the age, sex, duration of observations of height and bone age, and age in relation to menarche. This method requires rather greater care since its complexity increases the risk of errors in application, but if the claims of the authors are substantiated it promises a much greater degree of reliability than previous methods. A crucial factor in accuracy in these techniques is reliability in bone age estimations which must be undertaken by the method of TW2, and variations in these estimations alter greatly the predicted values.

Extent of the problem of invalid bone age estimation

A recent survey of paediatricians in England and Wales (182 of whom replied, and to whom I express my gratitude) indicated the current practice in bone age estimation. Seventy six per cent usually used the method of Pyle *et al.*, 20% that of Tanner and Whitehouse, and 4% other methods. About 12% of these paediatricians used more than one method, however, depending on the circumstances. About 25% of the paediatricians undertook the estimations themselves—equally distributed between those using the methods of Pyle *et al.* and Tanner *et al.*, but in the remaining 75% of centres the radiography department reported on bone age radiographs. In about half the places where Tanner and Whitehouse estimations are undertaken, these are done by the same one or two members of staff, whereas this is the case with only 32% of those estimating by Pyle's method. Thus most bone age estimations are not performed by any particular, experienced individuals.

From the foregoing comments the conclusion is probable that 75% of paediatricians may receive very misleading information which they would probably be better without. Only standards based on British children are valid for a British population. Where great accuracy is not essential, as often is the case in aiding diagnosis, a simple system may be adequate,¹ but for more precise needs in showing changes with time and in predicting adult height, accurate estimates by the TW2 method are essential. This demands experienced, enthusiastic observers (pre-

ferably the same ones), who are willing to spare the time—and these are not always easy to obtain.

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