Hand wrist radiograph: A Critical Review

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Abstract

Several methods are used to assess the level of maturity attained by child during post natal growth. Children of same age vary in their maturity status a great deal, therefore biologic maturity indicators have been developed to assess the progress towards full maturation of an individual at various times during growth. The bone age of a child indicates his/ her level of biological and structural maturity better than the chronological age calculated from the date of birth. The accurate age assessment is required for applying correct treatment modality in pediatric patient as well as for forensic purpose. The hand wrist radiograph is considered to be the most standardized method of skeletal assessment. In the present review we will discuss about the various methods of hand wrist skeletal maturity assessment.

Sources of Data/Study Selection: Recent articles published between years 2004-2015 obtained from online search engines Pubmed and Google Scholar were used in preparation of this review.

Key Words: Bone Age Measurement, Hand –wrist radiograph, Chronological age, Gruelich and Pyle atlas

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Introduction

The most commonly and easily determined developmental age parameter is the chronologic age, which is simply figured from the child's date of birth. It is neither an accurate indicator of stage of development nor it is a good predictor of growth potential.[1] Other parameters such as skeletal age or bone age, mental age, dental age etc. are more reliable methods. Skeletal age or bone age refers to the degree of ossification and development of the bone.[2]

Bone age is often requested by pediatricians and endocrinologists for comparison with chronological age for diagnosing diseases which result in tall or short stature in children. Serial measurements are also used to assess the effectiveness of treatment for these diseases.[3]

Age assessment is important for various other reasons. The first reason is increasing number of unidentified cadavers and human remains, the second reason is rise in cases requiring age determination in live individual with no valid proof of date of birth.[4] Thus need for accurate estimation of age arises in conditions where the age of a child needs to be accurate, such as during immigration[5], in law suits[6] and in competitive sports.[7] In these cases bone age is used to provide the closest estimate of chronological age. The hand wrist radiograph is considered to be the most standardized method of skeletal assessment.[8]

Through this review we have tried to compare the efficacy of various methods using hand wrist radiographs for age determination and to assess the reliability of the same.

Bone age by visualization of Hand & Wrist bones

The hand – wrist region is made up of numerous small bones. These bones show a predictable and scheduled pattern of appearance, ossification and union from birth to maturity. Hence, this region is one of the most suited to study growth.[9] Assessment of skeletal maturity from radiographs of the hand and wrist is based on changes in the developing skeleton that can be easily viewed and evaluated on the standardized radiograph. Traditionally, the left hand and wrist are used. The hand and wrist are placed flat on the X-ray plate with the fingers slightly apart; when film is viewed, the hand wrist skeleton is observed from the dorsal (posterior or top side) as opposed to the palmer (anterior) surface.[10] The hand radiographs are quite safe to obtain as the effective dose of radiation received during each exposure is between 0.0001-0.1 Msv.[11] This dose is less than 20 minutes of natural background radiation or the amount of radiation received by an individual on a 2 minutes transatlantic flight.[1]

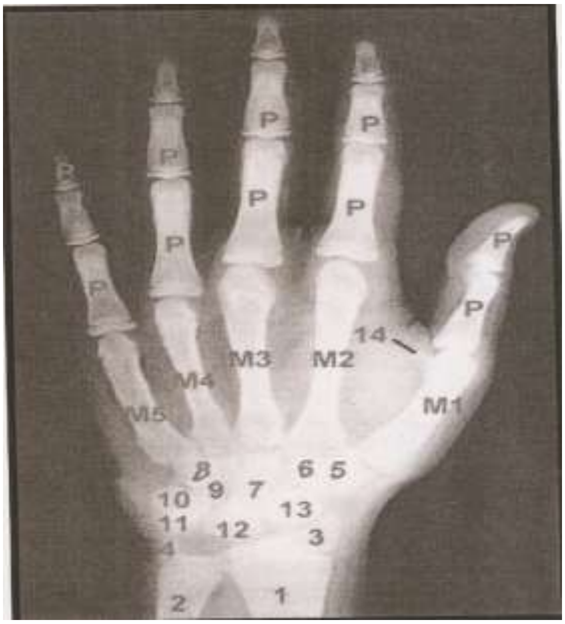

Fig. 1: Anatomy of the skeleton of the hand

(1)Radius (2) ulna (3) distal epiphysis of radius (4) distal epiphysis of ulna (5) trapezium (6) trapezoid (7) capitate (8) hamular process of hamate (9) hamate (10) triquetral (11) pisiform (12) lunate (13) scaphoid (14) sesamoid, M = metacarpal, P = phalynx

1. **Gruelich-Pyle[12] (G.P) method:** Various methods describing the use of the hand and wrist radiographs for the skeletal age assessment are discussed. The Gruelich-Pyle[12] (G.P) method devised in 1959 is based on the original work of Todd[13] done in 1937 or sometimes called as atlas, or inspectional, method. The atlas contains reference images of male and female standards of the left wrist and hand from birth till 18 years for females and 19 years for males. Also, explanation regarding the gradual age related changes observed in the bone structure is provided with each standard image[14]. The method entails the matching of a hand – wrist X-ray of a specific child as closely as possible with a series of standard X-ray plates, which correspond to successive levels of skeletal maturity at specific chronological ages.

A child's skeletal age (S.A) is the age identified as typical of the sex-specific standard plate with which a given child's film most closely coincides. Thus, if the hand wrist X-ray of a 7 year old child matches the standard plate of 8-year-old children, the child's SA is 8 years. This method is simpler and faster than other radiograph based methods.

2. **Tanner Whitehouse (TW2) Method:** The Tanner &Whitehouse (TW) method in contrast is not based on the age, rather it is based on the level of maturity for 20 selected regions of interest (ROI) in specific bones of the wrist and hand in each age population.[15] The Tanner – Whitehouse (TW) is sometimes called the bone-specific approach (Tanner et al. 1962[16], 1975[17]). It was developed on a cross – sectional sample of about 3,000 healthy British children. The method entails matching the features of 20 individual bones on a given film to a series of specific, written criteria for the stages through which each bone passes in its progress from initial appearance to the mature state. The 20 bones include the seven carpals (excluding the pisiform) and 13 long bones (radius, ulna, and metacarpals and phalanges of the first, third, and fifth digits).

The development level of each ROI is categorized into specific stages labeled as (A, B, C, D- I). A numerical score is given to each stage of development for each bone individually. By summing up all these scores from the ROIs, a total maturity score is calculated. This score is correlated with the bone age separately for males and females.[15]

3. **Fels Method:** The Fels method for assessing skeletal maturity of the hand – wrist was developed on children in south – central Ohio, who were participants in the Fels Longitudinal Study. The study was done by Roche et al.[18] in 1988. The sample was largely middle class. Maturity indicators for each bone of the hand and wrist were initially defined and their presence then verified. The reliability of each indicator was established and then validated on a separate set of radiographs.

Reduntant indicators were eliminated to reduce the number that must be assessed. Criteria for specific grades of each maturity indicator were based on the shapes of each carpal bone and the epiphyses and corresponding diaphyses of the radius and ulna and of the metacarpals and phalanges of the first, third and fifth digits. The presence or absence of the pisiform and adductor sesamoid of the first metacarpal were also used.

Grades were assigned to the indicators for each bone by matching the film being assessed to the described criteria. Ratios of the linear measurements of the widths of the epiphysis and metaphysis of each of the long bones were also used. In converting the grades and ratios to an SA (skeletal age) at a given chronological age, the maximum likelihood method was used. This statistical approach selects the most appropriate indicators of skeletal maturity for each chronological age and in males and females. Hence, different maturity indicators were involved in assessments at different chronological ages.

In this manner redundant assessments and information were reduced. The values for the measured (epiphyseal and metaphyseal) widths and graded (assigned grades for specific bones) maturity indicators were entered into a micro-computer that calculated the SA and a standard error of estimate for the SA. The standard error provided an indication of the error inherent in the assessment. Other methods of assessing skeletal maturation do not provide an estimate of error associated with the assessment.

4. **The Gilsanz & Ratibin (GR) Atlas:** A new digital atlas was developed by Vicente Gilsanz and Osman Ratibin[19] in 2005. In the past, determination of bone maturity relied on visual evaluation of skeletal development in the hand and wrist, most commonly using the Greulich and Pyle atlas. The Gilsanz and Ratib digital atlas takes advantage of digital imaging and provides a more effective and objective approach to assessment of skeletal maturity. The atlas integrates the key morphological features of ossification in the bones of the hand and wrist and provides idealized, sex- and age-specific images of skeletal development. The images of the new GR atlas are much more precise and have a better quality than those of the older GP atlas.[20] Also these new GR atlas standards are spaced at regular 6 monthly intervals from the ages of 2 to 6 and at yearly intervals from age 7 to 17. Lin FQ[21] et. al in 2015 compared the validity of GR and the Greulich-Pyle (GP) atlas in Bone assessment determination for children in Shanghai. They concluded that both atlases can be used on most age groups. However, the GR atlas is not recommended in boys aged 10-13 years, while the GP atlas is not suitable for girls aged 0-3 years. Therefore, the use of the GP or GR atlas is practical, depending on the age of the child.

5. **Automatic Skeletal Bone Age Assessment:** Automatic skeletal age assessment are computer assisted assessments , they have the potential to reduce the time required to examine the image and to increase the reliability of the analysis.[22] In all the developed method the algorithms are divided in several step: image preprocessing, background removal, orientation correction, image segmentation and features analysis.

The first semi-automated system was developed by Michael[23] around the 1989. The author claims that the system was able to automatically segment the bones in a hand radiograph but large scale tests were not done. Before segmentation starts, the image is first preprocessed. The goal of this preprocessing is to normalize the image gray scale so that the later segmentation step will be more robust. The program first segments the entire hand (bones and flesh) from the background using a thresholding operation. After this a model-based method is used to find the bones in the hand. This method uses knowledge of the relative positions of the bones in the hand with respect to each other and to the contour of the hand. After the approximate position of a bone is found its contour is given by an adaptive contour following algorithm. Then the image is analyzed by taking account of selected regions of interest for calculating bone age by Tanner-Whitehouse method or by comparison with standard images for estimation by Greulich & Pyle Atlas.

De Sanctis V[1], Soliman AT, Di Maio S, Bedair S.[24] developed Computerized and Quantitative Ultrasound Technologies (QUS) for assessing skeletal maturity with the aim of reducing many of the inconsistencies associated with radiographic investigations. In spite of the fact that the volume of automated methods for bone age assessment has increased, the majority of them are still in an early phase of development. QUS is comparable to the GP based method, but there is not enough established data yet for the healthy population. Mari Satoh[25] in 2005 developed an automated method for determining bone age, named BoneXpert, which has been validated for Caucasian children with growth disorders and children of various ethnic groups

Conclusion

Skeletal age assessment is one of the most reliable methods for assessing developmental age. The correct estimation of developmental age is required by pediatric endocrinologist and pediatric orthopaedic surgeon for choosing the effective treatment procedure in a child patient. Moreover, the accurate age assessment has its importance in forensics also. Therefore various bone age assessment methods especially the hand –wrist radiography is a boon for medical science. Various methods of hand –wrist assessment has been devised, the latest being the automated systems. From the above review we can conclude, that no method of hand wrist radiography is flawless and lot of research is required in this direction to obtain a desired hand wrist radiographic technique for skeletal age assessment.

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