# MEASUREMENT OF CARPAL BONES: COMPARISON BETWEEN SONOGRAPHIC METHOD AND STANDARD RADIOGRAPHIC METHOD IN NORMAL CHILDREN IN HUSM KUBANG KERIAN KELANTAN

By

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## LISTS OF ABBREVIATIONS

| | |
|---|---|
| AP | Anteroposterior |
| BA | Bone age |
| CA | Chronological age |
| CI | Confidence interval |
| CT | Computed tomography |
| DFE | Distal femoral epiphysis |
| FHC | Femoral head cartilage |
| GP | Greulich and Pyle |
| HUSM | Hospital Universisti Sains Malaysia |
| ICC | Intraclass correlation coefficient |
| MRI | Magnetic resonance imaging |
| MHz | Megahertz |
| PS software | Power and Sample Size Calculation Software Version 2.1.31 |
| RG | Radiograph |
| SD | Standard deviation |
| SPSS | Statistical Package for Social Sciences version 12.0.1 |
| TW2 | Tanner and Whitehouse |
| US | Ultrasound |

## LISTS OF SYMBOLS

| | |
|---|---|
| mSv | milisicverts |
| n | number of sample |
| $\alpha$ | Type 1 error probability for 2 sided test |
| $\sigma$ | standard deviation of difference |
| $\delta$ | a difference in population means |
| < | less than |
| = | equal to |
| > | more than |

## ABSTRAK

**Tajuk:** Ukuran tulang karpus: Perbandingan antara kaedah sonografi dan kaedah radiografi biasa dikalangan kanak-kanak normal di HUSM Kubang Kerian Kelantan.

**Tujuan:**

1. Menentukan samada tulang karpus boleh dikesan melalui kaedah ultrasonografi dan mengukur saiz setiap tulang karpus yang boleh dikesan serta membandingkan dengan radiograf tangan kiri.
2. Menentukan perbezaan ukuran tulang karpus melalui kaedah ultrasonografi dan radiograf.
3. Menentukan perbezaan antara pemerhati dalam menentukan usia tulang.

**Kaedah and Bahan:** Seramai 24 orang kanak-kanak normal telah mengambil bahagian dalam kajian ini dalam menentukan usia tulang daripada April 2005 sehingga Oktober 2006. Setiap daripada mereka telah menjalani pemeriksaan radiografi tangan kiri dan ultrasonografi pergelangan tangan kiri. Pemeriksaan ultrasonografi dilakukan ke atas tulang karpus untuk menentukan kewujudannya dan mengukur saiznya. Usia tulang ditentukan dengan membandingkan radiograf tangan kiri dengan atlas Greulich dan Pyle. Ukuran tulang karpus melalui kaedah ultrasonografi dibandingkan dengan kaedah radiografi, perbezaan dan persetujuan antara dua kaedah dianalisa. Perbezaan antara usia tulang dan usia sebenar, perbezaan antara dua pemerhati juga dianalisa.

**Keputusan:** Min usia tulang ialah 8.38 ± 3.45 tahun dan usia sebenar ialah 8.79 ± 2.73 tahun. Kesemua kanak-kanak, tulang karpus yang dilihat pada radiograf telah dikesan wujud melalui pemeriksaan ultrsonografi. Pusat ossifikasi dalam bentuk rawan telah dikesan melalui kaedah ultrasonografi tetapi tidak dikesan melalui radiograf dalam 3 subjek. Didapati hubungkait yang bagus diantara ultrasonografi dan radiografi dalam pengukuran saiz tulang karpus (ICC=0.907). Persetujuan antara 2 pemerhati dalam menentukan usia tulang adalah tinggi (ICC=0.988). Min perbezaan antara usia sebenar dan usia tulang adalah 0.40 ± 1.304 tahun dan tidak signifikan.

**Kesimpulan:** Kaedah ultrasonografi boleh mengesan pusat ossifikasi rawan. Walaupun hubungkait yang bagus didapati antara 2 kaedah, saiz ukuran tulang karpus sahaja tidak boleh digunakan untuk menentukan usia tulang. Sebaliknya kaedah ultrasonografi akan lebih bermakna jika di gabungkan dengan kaedah radiografi.

## ABSTRACT

**Title:** Measurement of carpal bones: Comparison between sonographic method and standard radiographic method in normal children in HUSM Kubang Kerian Kelantan.

**Objectives:**

1. To determine the presence of carpal bones by ultrasound and to measure the diameter of the visualized carpal bones, comparing with gold standard left hand radiograph.
2. To determine the difference in measurement of the carpal bones by ultrasound and radiograph.
3. To determine the difference in bone age assessment between 2 observers.

**Methods and Materials:** Twenty four (24) normal children were evaluated for bone age from April 2005 until October 2006. Each child was examined by standard left hand radiograph and ultrasound examination of the left wrist. Sonographic examination was performed on the carpal bones to see its presence and to measure the transverse diameter. Bone age was evaluated by comparing the left hand radiograph with the standards of Greulich and Pyle atlas. Diameter of carpal bones measured by ultrasonography and radiograph was compared, the mean difference and agreement between 2 methods were calculated. Mean difference between bone age and chronological age, and interobserver difference were also calculated.

**Results:** Mean bone age and chronological age was 8.38 ± 3.45 years and 8.79 ± 2.73 years respectively. In all cases, the carpal bones which were seen on radiograph were detected by ultrasound. Cartilaginous ossification centers were detected by ultrasound but not demonstrated on radiograph in 3 subjects. Good correlation was found between ultrasound and radiograph (ICC of 0.907) in the measurement of carpal bones. A high degree of agreement was found between 2 observers in the assessment of bone age (ICC of 0.988). The mean difference between chronological age and bone age was 0.40 ± 1.304 years and was not significant.

**Conclusion:** Sonographic examination was able to detect cartilaginous ossification centers at the wrist. Even though there was a good correlation between the 2 methods, the diameter of carpal bone alone cannot be used to determine bone age. Ultrasonographic evaluation is more valuable if combined with radiography of the hand.

# SECTION ONE:

# INTRODUCTION

# 1 INTRODUCTION

By looking at the bone maturation, one can guess a child's age. This is called bone age or skeletal age. Bone maturation is marked by an orderly sequence of recognizable changes in the appearance of the skeleton during childhood. Such changes include the timing and sequence of the appearance of the centers of ossification, specific alterations in the contours of the bones, and the timing and sequence of the ultimate closure of the growth plates.

Skeletal age estimation is a valuable adjunct in clinical pediatrics, enabling recognition of growth derangements in children and young adults. Skeletal age assessment is a frequently requested procedure in pediatric radiology, as many diseases and disorders affect bone growth resulting in discrepancy between bone age and chronological age. Skeletal age is frequently used in making the diagnosis of musculoskleletal disorders caused by endocrine or congenital disorders which is associated with delayed or advanced skeletal maturation (Evans et al.), to assess response to medical therapy in patients who are treated with hormones, to predict the ultimate height (Greulich and Pyle, 1959), to predict sexual maturation prior to puberty and to determine the timing of closure of an epiphysis in a child with leg-length discrepancy. Skeletal age assessment is also frequently requested as part of the evaluation of children who are either too tall or too short for their chronological age.

The most commonly used methods for skeletal age assessment are Greulich and Pyle [GP] (Greulich and Pyle, 1959) and Tanner and Whitehouse [TW2] (Tanner et al., 1983). GP is the most commonly used standard for skeletal maturation because it is simple, convenient and fast. The GP method uses the radiograph of the left hand and wrist compared with a series of standard radiograph to which a particular bone age has been attributed.

Other methods include Risser method (Neuwirth and Osborn, 2001), (Herman and Pizzutillo, 2002), (Wagner et al., 1995), (Rauzzino et al., 1999), (Lonstein and Winter, 1994), (Durkin, January 2003) which are important in the management of scoliosis, Sauvegrain method (Dimeglio et al., 2005) used during puberty and assessment of the medial end of clavicle (Kreitner et al., 1998).

Radiographic evaluation of skeletal assessment use ionizing radiation. Thus several ultrasound-based techniques have been developed for estimation of skeletal age. These techniques are also based on the ossification centers of the growing epiphyseal plate. Some of the techniques used are the evaluation of the thickness of femoral head articular cartilage (Wagner et al., 1995), (Castriota-Scanderbeg et al., 1998), dimension of the distal femoral epiphyseal ossification center (Paesano et al., 1998) [12] and carpal bones (Bilgili et al., 2003).

The sonographic method is safe in the context of radiation because it does not use ionizing radiation. Therefore, this method should be seriously considered as an alternative method. The aim of this study was to compare the sonographic method and standard radiographic method in the evaluation of skeletal age.

# SECTION TWO:

# LITERATURE REVIEW

## 2 LITERATURE REVIEW

Skeletal development refers to the development of the human skeletal system from the early days of pregnancy until the bones have reached full development in late puberty.
The early development of the skeletal system begins in third week after conception with the formation of the notochord, followed by the first signs of arms and legs in the fourth week. Between the fifth and eight weeks, the limbs (first the arms, hands and fingers, followed by the legs, feet and toes) begin to extend and take on a definite shape.
By the end of the fifth week, the embryo has doubled in size and has grown a tail-like structure that becomes the coccyx. By the seventh week the embryo is about 2cm long and facial features are visible. At this stage, the 206 bones of the human body are all set down. However the process of osteogenesis has not progressed to the point where the bones are 'bony'. Ossification of most bony nuclei of the long bones and round bones does not complete until after birth.

Many ossification centers (hand, foot, knee, elbow and pelvis) are not visible by radiography until they begin to mineralize or ossify, even though they are actually present long before such mineralization begins. The age at appearance of individual ossification centers then become useful measures of skeletal development and especially in the form of 'bone age' assessment of the hand, foot or knee.

According to Dorland's Medical Dictionary (Becker et al., 1989), skeletal age is defined as the stage of development of the skeleton of an individual in terms of the average chronologic age of normal individual with the same degree of skeletal development. In the living, this is determined for all practical purpose by radiologic evidences of the closure of the fontanelles in infants and small children, and by the extent of ossification of the cartilages of the wrist and hand in older children and adolescent. In adults the estimate depends mostly on the extent of synostoses of the cranial sutures.

Chronological age is defined as age as measured in time elapsed since birth.

## 2.1 Methods of determination of skeletal maturation

### 2.1.1 Greulich and Pyle (Greulich and Pyle, 1959)

GP method is the most commonly used method for assessing skeletal maturation. The GP method for evaluation of skeletal maturity depends on the appearance, size and differentiation of various ossification centers and the degree of fusion between the epiphysis and shafts of the bones of the left hand and wrist. The standards were developed from a longitudinal radiographs of white children in the Cleveland area between 1931 and 1942. For the most part, these children were from families at a mid to upper level of socio economic statutes. The standards were selected at three month intervals during first postnatal year, at six month intervals from one to five years of age, and annually thereafter. Standards for male and female child were produced separately.

The GP technique defines certain maturity indicators, which are demonstrated in line drawings at the end of the text and in the text opposite the photographs of each standard radiograph. These are features that regularly recur in each individual and mark their progress toward maturity. These indicators include the appearance of ossification in various ossification centers, the relationship of the epiphysis to the shaft of the bone and the presence of capping of epiphysis or indentations in bones and fusion of epiphysis to metaphysis. Because no individual 'standard' radiograph was perfect for each individual bone, the text opposite each standard radiograph lists the estimated skeletal age of each individual bone in the accompanying radiograph.

Although the recommendations of GP include obtaining a skeletal age for each bone in hand and wrist and average them, this is impractical and most radiologists compare the patient's radiograph with the various standard radiographs in the atlas to obtain the 'best match'. The range of ± 2 standard deviations (SD) should be considered normal. Tables of standard deviation for various chronological ages are available in the GP atlas.

The GP method is extremely useful at any ages. However, in children less than 2 years of age, there is relatively little change in the ossification centers of the hand and wrist, but there are relatively rapid changes in the ossification of the knee and foot. Standards for skeletal maturity in these regions are often helpful in these children. In children between 8 and 12 years of age, the changes in the hand and wrist are relatively subtle. Therefore some authors have suggested using available standards for the pediatric elbow in addition to the GP method in this age group (Dimeglio et al., 2005).

***a) Why left hand?***

In GP atlas, the left hand and wrist radiograph was used for skeletal assessment. Left hand rather than right hand radiograph was used because of a number of considerations. First of all, the International Agreement for the Unification of Anthropometric Measurements to be made on Living Subjects drawn up at the Monaco and Geneva Conferences of Physical Antropologist in 1906 and 1912, respectively specified that measurements has to be made of the left rather than the right side of the body and of the left extremities. Another consideration was the fact that the number of right-handed persons in most populations is much larger than the number of left-handed ones and that, consequently the left hand is somewhat less likely to be injured than the one which is used more frequently.

However, there are studies comparing the left and right hand radiograph. Dreizen et al in 1957 did a study comparing the right and left hand films of 450 children. The conclusion was although homologous part of the two sides of the skeleton may show considerable difference in development, discrepancies between the two sides are too insignificant to constitute a source of error in determination of skeletal status. The difference between the skeletal ages of the two hands exceeded 3 months in only 13 percent of the children and more than 6 months in only 1.5 percent.

*b) How to read the radiograph ?*

The most commonly used method is by comparing the hand radiograph with the standards illustrated in the atlas. Begin by comparing the film to be assessed with the standard of the same sex and nearest chronological age in the atlas. Next the film is compared with adjacent standard, both older and younger than that of the nearest chronological age. Skeletal age for a more detailed comparison from the standard is selected which superficially appears to resemble it most closely.

During infancy and early childhood the presence or absence of certain carpal or epiphyseal ossification centers will provide the most useful clue. Beginning at about the time of puberty and ending in late adolescence, the degree of fusion of epiphysis with their shafts furnishes additional information that will be helpful in making the preliminary selection. During the intermediate period, the selection will depend more upon those changes in the shape of the bones and on other skeletal features visible in the hand-film which are described in the list of maturity indicators. The maturity indicators provide also the basis for the detailed assessment of the hand-film throughout the entire period from birth to early adulthood.

After finding the standard which superficially resembles most closely the film to be assessed, one should proceed to make a detailed comparison with individual bones and epiphysis visible in them. A good way is to begin at the distal ends of the radius and ulna, proceeding next to the carpals, then to the metacarpals, and then to the phalanges. The carpal bones should be studied in a regular sequence, preferably in the order in which they usually appear: Capitate, Hamate, Triquetral, Lunate, Scaphoid, Trapezium, Trapezoid and Pisiform. The adductor and flexor sesamoids of the thumb appear in that order, usually several years after the pisiform has begun to ossify. If an individual bone in the film to be assessed is in the same stage of development as the corresponding bone in the standard selected for the detailed comparison, it should be given the skeletal age that has been assigned to that bone in that standard.

In evaluating the skeletal age of individual children one needs to know whether or not the extent to which they are advanced or retarded on the basis of these standards is to be regarded as significant. In this atlas, tables for standard deviations of the skeletal ages for those children are shown for girls and boys. It is probably safe to assume one standard deviation above and below the skeletal age corresponding to the child's chronological age.

A difference of more than two standard deviations above or below the mean would make it highly probable that the child is abnormally advanced or retarded.

This method has the advantages of simplicity, fast, convenience and availability of multiple ossification centers for the evaluation of maturity (Milner et al., 1986), (King et al., 1994). However the applicability of this method has been questioned when applied to certain ethnic and racial differences of different population. Variations in skeletal maturation were shown between children of Europeans and Africans (Mora et al., 2001).

Applicability of GP method to different ethnic group was studied. A study by Loder et al (Loder et al., 1993), showed that the GP atlas was not applicable to all children, especially black girls. Because racial diversity and racial mixing in the United States were increasing, reevaluation of the use of skeletal age standard by GP method was conducted in children of different ethnic groups (Ontell et al., 1996). The conclusion was that, the sex and ethnicity must be considered when using the standards of GP to determine bone age particularly in black and Hispanic adolescent girls and Asian and Hispanic adolescent boys.

In Malaysia, this GP atlas can be used with a good degree of confidence for Malaysian children aged 12 to 28 months. A study done by Chen et al (Chen et al., 1990) found that 83.4% of males and 94.8% of females were matched within the ± 6 months discrepancy range.

### 2.1.2 Tanner-Whitehouse Method (Tanner et al., 1983)

Tanner et al. developed standards for skeletal maturity using radiographs of the hand and wrist based on a British population of children. This technique requires individual evaluation of 20 different bones of the hand and wrist. Each bone is assigned one of eight maturational stages. Each individual score is then multiplied by a fractional multiplier to determine a score for that bone. A score for the radius, ulna and phalangeal bones (RUS score) is obtained by adding the score for seven of the carpal bones (the pisiform is excluded). The RUS and carpal scores are then averaged to determine an overall TW2 score (ranging from 0 to 100). The skeletal age is determined by plotting the TW2 score on a chart of TW2 score over skeletal age. Although little utilized in a clinical setting in the United States, this technique is sometimes used as a research tool.

TW2 method is more tedious than GP method. Several studies have compared the TW2 and GP methods (Milner et al., 1986), (King et al., 1994) and have suggested that there is close agreement between them. However another large scale study comparing these two methods (Bulla et al., 1999) concluded that the GP and TW2 method produced different values for bone age, which were significant in clinical practice. The TW2 method was more producible than GP method. They hypothesized that the rapid GP method, as used in common clinical practice is potentially less accurate than the more rigorous and time consuming TW2 method. Therefore they suggested that one method only (preferably the TW2) should be used when performing serial measurements on an individual patient.