Age Determination by Radiology

© **Dr. Rajneesh Kumar Sharma** MD (Homoeopathy)
Homoeo Cure Research Institute
NH 74- Moradabad Road
Kashipur (UTTARANCHAL) - INDIA
Ph- 09897618594
E. mail- **drrajneeshhom@hotmail.com**
www.homeopathictreatment.org.in
www.treatmenthomeopathy.com
www.homeopathyworldcommunity.com

Introduction

Abstract

From the moment of birth until the time one has grown up, bones go through a set a characteristic changes. Therefore the skeletal maturity, or bone age, can be estimated from radiographs of specific bones in the human body. Children who grow exceptionally slow or fast are often examined by making a radiograph of their left hand and wrist. This all is due to a variety of internal and external factors. Extracellular substance and bone cells get old and characteristic structural remodeling occurs with age. These age-related changes are important in the discrimination between pathological and physiological changes during old age. About 20% of the bone mass is lost between the fourth and the ninth decades, osteoblasts function less efficiently, and gradual loss of bone substance is enhanced by delayed mineralization of an increased surface area of thin and relatively less active osteoid seams. After the fifth decade, osteoclasia and the number of Howship's lacunae increase and, with age, the number of large osteolytic osteocytes increases as the number of small osteocytes declines and empty osteocyte lacunae become more common. The result is greater liability to fracture and diminished healing or replacement of injured bone.

Bone maturation

In the fetus, bone is formed in two ways, either from condensed mesenchymal tissue to form intramembranous bone, or from endochondral bone by the indirect conversion of an intermediate cartilage model. Intramembranous ossification occurs in the bones of the cranial vault, i.e. the frontal bones and parietal bones, and in parts of the occipital bones and temporal bones, the mandible and maxilla. Endochondral bone formation takes place at the base of the skull, and the vertebral column, pelvis and the bones of the extremities, although mesenchymal bone formation can also be seen in these locations. Bone formation occurs in ossification centres that are usually located centrally within the mesenchymal tissue or in the cartilaginous model. Secondary ossification centres appear later and are located at the end of the cartilage models within the epiphysis and the apophysis. In tubular bone ossification proceeds towards the ends of the bones, where it beomces better delineated and appears as a plate of cellular activity. This plate is located between the epiphysis (secondary ossification centre) and the diaphysis forming the growth plate (physis) that later becomes the site of longitudinal growth of the bone. The ossification centres of the epiphysis and the ossification centres of the small bones of the wrist appear at different ages.

In the vault, the cerebral capsule is divided into several fields and in the centre of these fields, just outside the dura, the ossification centres appear for the two parietal bones, the two temporal squamae, the paired centres for the frontal bone and the two centres for the interparietal portion of the occipital bone. Each ossification centre enlarges towards fibrous tracts that define each field. At these borders, where the ossification boundaries of each field meet, the sutures are formed. More bone is added to the periphery of each ossification centre when the cerebral capsule expands, i.e. with the subsequent enlargement of the neural mass.
The vertebral body is formed by eight ossification centres, that at birth usually are fused to one, often with a sagittal or coronal cleft. The vertebral arch is ossified from one or two centres on each side, and is fused to the body by the neurocentral synchondrosis, that ossifies at about 4 years of age. The final shape of the vertebral body is formed by the ring apophysis that fuses to the rest of the body at adolescence.
Fig.1, Fig.2, Fig.3, Fig.4, Fig.5, Fig.6, illustrates bone maturation in a series of hand radiographs ranging from the age of three months to 18 years, Fig.7 shows the pelvis in a 16-year-old adolescent, and Fig.8, Fig.9 and Fig.10 is the skull in a 6 month-old infant, and Fig.11 and Fig.12 displays the bone maturation in the vertebral column in a newborn and a 14-year-old.

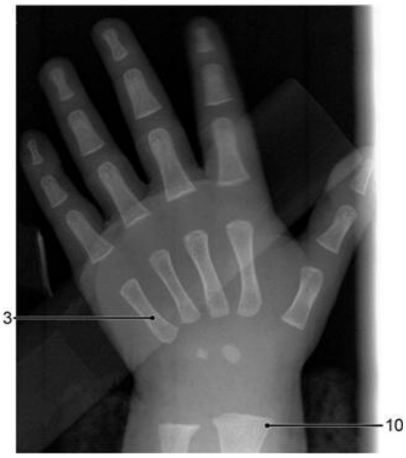


Fig.1 hand 3 months

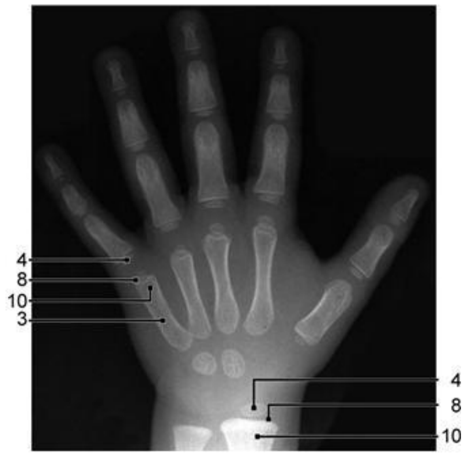


Fig.1 hand 3 years

Fig.3 hand 6 years

Fig.4 hand 10 years

Fig.5 hand 13 years

Fig.6 hand 18 years

Fig.7 Pelvis 16 years

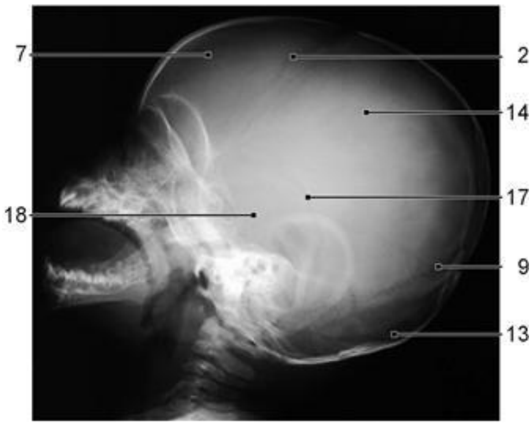


Fig.10 Lateral radiograph of the skull, age 6 months.

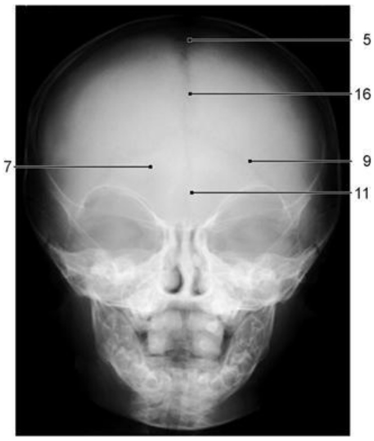


Fig.8 Skull 6 months

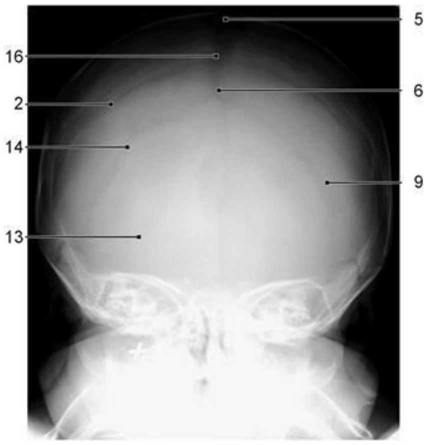


Fig.9 Half axial projection of the skull, age 6 months.

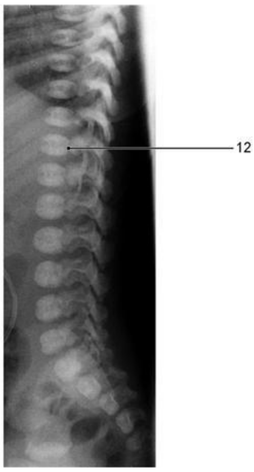
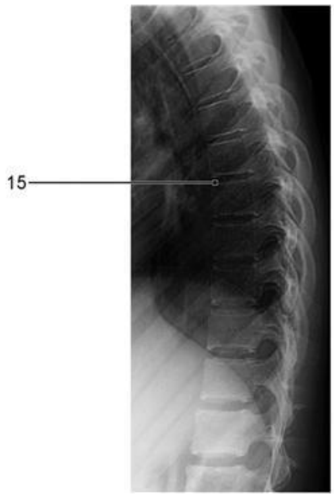


Fig.11 Spine, radiograph, lateral projection, newborn



Spine, radiograph, lateral projection, age 14 years

1.	Apophysis	Fig. 7
2.	Coronal suture	Fig. 9, Fig. 10
3.	Diaphysis	Fig. 1, Fig. 2, Fig. 3, Fig. 4, Fig. 5, Fig. 6
4.	Epiphysis	Fig. 2, Fig. 3, Fig. 4, Fig. 5, Fig. 6
5.	Fontanelle, anterior	Fig. 8, Fig. 9
6.	Fontanelle, posterior	Fig. 9
7.	Frontal bone	Fig. 8, Fig. 10
8.	Growth plate	Fig. 2, Fig. 3, Fig. 4, Fig. 5
9.	Lambdoid suture	Fig. 8, Fig. 9, Fig. 10
10.	Metaphysis	Fig. 1, Fig. 2, Fig. 3, Fig. 4, Fig. 5, Fig. 6
11.	Metopic suture	Fig. 8
12.	Neurocentral synchondrosis	Fig. 11
13.	Occipital bone	Fig. 9, Fig. 10
14.	Parietal bone	Fig. 9, Fig. 10
15.	Ring apophysis	Fig. 12
16.	Sagittal suture	Fig. 8, Fig. 9
17.	Squamous suture (of cranium)	Fig. 10
18.	Temporal squama	Fig. 10

Bone maturation Table showing Legends

Age Determination

Although the actual age can not be determined by bones, the approximate age of the individual can be ascertained.

For age determination, different parts of the skeleton are more useful at different age ranges. The different age ranges include perinatal, neonate, infants and young children, late childhood, adolescence, young adult, and older adult.

Perinatals

The age of perinatals, those that are not yet born, can be determined by looking at bone size. This is because outside factors such as malnutrition on the mother's part is not going to affect the fetus' growth as much. During periods of low food intake the mother's body will give nutrients to the fetus, shorting the mother of nutrients.

Neonates

Neonates, babies who have not gotten their teeth yet, are very difficult to accurately determine the age of because of individual variation of development. As a group, the neonates have no teeth, many areas of the skeleton have not fused together (especially the cranium and pelvis), and they have very small bones.

Infants

Infants and young children will usually have some of their teeth in. The formation of teeth is often used in age determination for this group. Permanent teeth start to form at birth, thus the formation of permanent teeth is a relatively good age determinant. Some ossification has begun in the bones at this age, this means that soft parts of the bones become hard. However, this is not as good a determinant.

Late childhood

Late childhood is when the permanent teeth begin to come in. More bones begin to ossify.

Adolescence

Adolescence shows increased long bone length and fusion of the ends (or cap) to the shaft. This fusion is a particularly useful age technique. Each cap, or epiphysis, fuses to the shaft, or diaphysis, at a particular age range.

Young and older adults

Young adults and older adults have several methods of age determination: closure of the cranial sutures; morphology of rib-ends, auricular surface and pubic symphysial; microstructure of bone and teeth; wear on teeth, incremental layers of cementum; and finally the 'Complex Method'.

Cranial sutures (non-movable joints in the head) slowly fuse together, becoming obliterated in time. Although this has been known for many years, there has only been a weak association established between age and closure.

The morphology of rib-ends changes through age. Ribs are connected to the sternum by cartilage. The rib ends that meet with the cartilage are relatively flat at first, but during the aging process the ends become ragged and the cartilage becomes pitted. The irregularity of the rib ends has been found to relate to age at death.

Dental age determination

Dental age determination is based on the radiography of the mandible. This is called an orthopantomogram. All the teeth are clearly demonstrated on the view obtained. The age determination is based on the presence of the teeth (baby and adult teeth) and their maturation, crown and roots. It can be used from the first years of life to 21 year-old. During adolescence, the shape of the roots of the second and of the third molars had to be analysed.

Skeletal age determination

From the radiograph below, the bone age can be estimated. From this estimate, together with other pieces of information such as the calendar age, sex and height of the child and possibly information about the parents, the adult height can be predicted. A big discrepancy between the calendar age and the bone age can indicate an atypical skeletal development. In many cases the decision whether to treat a child with growth hormones depends on the outcome of bone age estimation.

Elbow

The radiography of the elbow is a good tool between 9 to 13 years old. This study needs two exposures, an A.P. view and a lateral view to evaluate the presence and the maturation of the condyles, the radial capita and the proximal point of the ultia. A score is calculated and reported on a curve.

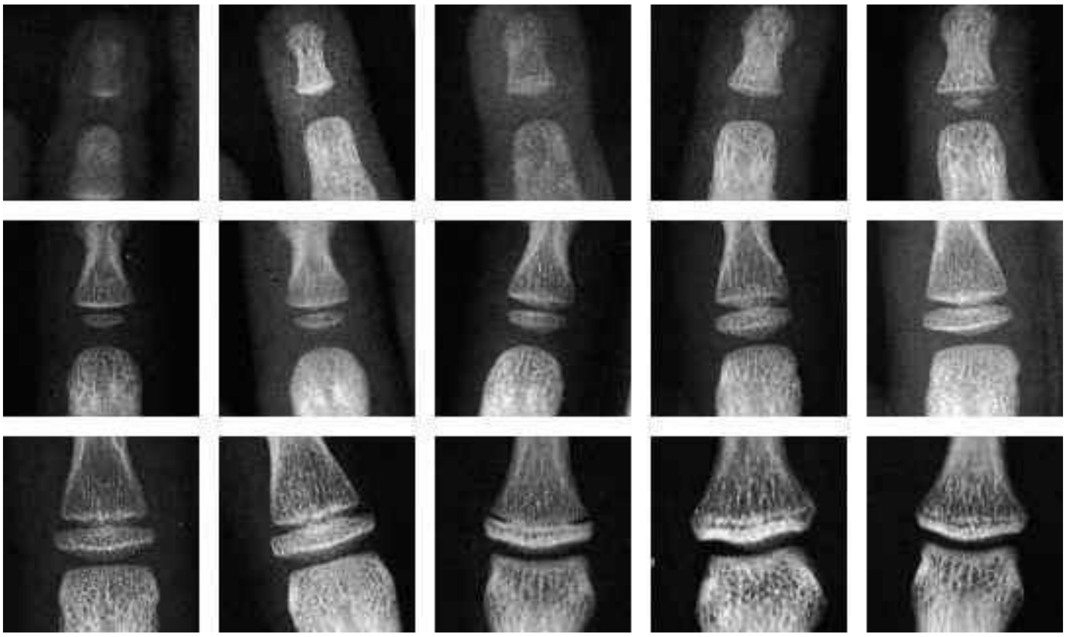
Iliac crest

To have other information about the bone age of a subject, some authors define the aspects of the maturation of the secondary ossification centre of the iliac crest. This study, whose name is Risser's test, is available between 12 to 16 years-old.

Clavicle

The age determination is based on the presence and morphology of the medial secondary ossification centre of the clavicle: this one appears at 12 and is assimilated to the adjacent bone at 25 years. The four grades of the maturation of the clavicle are illustrated with CT. The interval between each grade is quite large. If the grade 4 is reached, the age of the subject is over 22 years, and that could be sufficient to affirm that the patient has to be considered as an adult.
The accuracy of the radiological methods is between ± 6 months and 1 one year of precision. This gap represents a possible error from one to 2 years.

Hand radiograph of a 9 years old girl. The bone age is 8 years.



Development of the ring finger, row by row- The image top-left is from a baby, the image at the lower-right is from a nineteen year old. In the fifth image, the epiphysis appears, which becomes wider and in the final images fuses with the metaphysis.

Methods of Bone age Estimation

Assessment of skeletal maturation is done by assessing the ossification and maturation of the epiphysis of the hands and wrists and comparing them with standards. Two main systems are used:

- The Greulich and Pyle method: the radiograph of the whole hand and wrist is compared with images in the Atlas.
- The Tanner Whitehouse system: known as TW2. This is a method, in which a score is assigned to 20 of the epiphyses in the hand and wrist having compared them with the standards in the Atlas. The scores are summed and compared with standard tables.

Applications of Bone Age Determination

Bone age is one parameter used in predicting height. Bone age monitoring is done in children on growth hormone therapy, to identify the optimum time for corrective spinal surgery or leg lengthening. Prior to the ossification of the hand epiphysis the ossifation of the distal femora and upper tibial eiphyses and the calcaneum are used. The calcaneus ossifies at 24 weeks gestation, the distal femur at 36 weeks and the upper tibia at 38 weeks. Iliac crest epiphyses fuse between 16 and 20 years.

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