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Bone Age Estimation Using Clavicle Bone.

Marjan Mansourvar[1*], Maizatul Akmar Ismail[1], Sameem Abdul Kareem[1], Ram Gopal Raj[1], Fariza Hanum Nasaruddin[1], Saw Aik[2], Roshan Gunalan[2], Chermaine Deepa Antony[2]

[1]Faculty of Computer Science and Information Technology, University of Malaya, 50603 Kuala Lumpur, Malaysia

[2]Faculty of Medicine, University of Malaya, 50603 Kuala Lumpur, Malaysia

* Corresponding author: Marjan Mansourvar, Faculty of Computer Science and Information Technology, University of Malaya, 50603 Kuala Lumpur, Malaysia · marjan2012@siswa.um.edu.my

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ABSTRACT

Determination of bone age known as subject age estimation from clavicle bone is a critical part of forensic age estimation in criminal proceedingsespecially when evaluation is of individuals over 18 years of age. Clavicle bone is one of the long bones in a body that islast to fuse and this is the reason why it is useful for prediction of age in post-pubertal subjects. Recently, the clavicle bone and its development have been a subject of interest in medical research. This paper provides a review of the different methods for age estimation using clavicle bone.

Keywords: Forensic science, Clavicle,Forensic age estimation, Bone age, Skeletal maturation

Introduction

Age assessment (or skeletal age estimation) of unknown people is one of the important topics in forensic science as well as physical anthropology, to identify human and to evaluate the level of biological profiling [1-2]. Various aging techniques are available based on different parts of the body such as epiphyseal-diaphyseal union, hand, pelvis, ankle, hand-wrist and end of ribs [3]. However because of damaging taphonomic procedures and commingling elements, few of these age estimation methods of bone are useful in forensic practices [4]. Skeletal age estimation using long length bone is more accurate and secure than other aging methods based on rib, foot or even dental elements. The clavicle is one of the long length bone in human body used in a precise

method for age estimation [5]. This paper provides a review on achievements in skeletal age estimation from the clavicle bone and different methods for age estimation based on the clavicle.

The role of the clavicle in bone age assessment

The clavicle is a long bone in the human body and is considered the first bone in fetal development that starts with membranous ossification and contains a medullar cavity[6]. The clavicle bone involves two centers of ossifications known as medial and lateral that forms from the 5th week of intrauterine life and is completed during fetal period [7].

In 1994, Buikstra and Ubelaker suggested the growth of the medial clavicle could be a good indicator in forensic age estimation in both living and dead cases [8]. Their research on a large scale discovered that the time in developing epiphyseal in medial clavicle and the union of clavicular shaft can be utilized in identification of bone age.

Cartilage starts to grow after the osteoid matrix in clavicle is completed and this point is presented as a union of endochondraland ossification and membranous ossification. Around 80% of bone length of the clavicle is inclusive of medial cartilaginous mass rather than lateral mass [9]. When two ossification centers in clavicle join in the spatial position at the end of the bone, a special s-shape will be formed continuously during the 8th to 9th week. The bone achieve its completed form during the 11th week in infancy [10], then its development slows until the 5th year, has a big jump in growth after the 7th year and again it slows until puberty age. At puberty age the second center of ossification forms at the medial and lateral ends of the clavicle.

Tod and D'Errico [11] studied the fusion of medial epiphysis in 20th century but still there is not enough research on the role of the clavicle for estimation of bone age. Medial epiphyseal ossification starts during puberty age although it does not complete to the shaft until 10 years from its first appearance [12].

Medial clavicle bone has been confirmed as a suitable indicator for bone age assessment in adults. It is initially like a tiny spot of bone in the center and it gradually extends to fill the entire medial surface. Scheuer and Black [9] classified the period of maturation of clavicular in three levels: The first level appears between age 16 to 21 years with a well-defined medial clavicle flake; the second level is between age 24 to 29 years with most of the medial environment filled by flake and the last period is between 22 to 30 years with complete fusion. Szilvassy [13] from Australia also presented the same classification without any overlapping: the first level was defined between 18 to 20 years, the second time frame with active fusion defined between 21 to 25 years, and the completed period between 26 to 30 years.

Singhe and Chavali [14] stated that the clavicle bone in comparison to other long bones in the body shows the longest time of growth activity in humans, so its predictive value can be considered as an effective and credible indicator for bone age assessment during the 30 years when other bones will have been inactive in human life.

In addition, among long bones in the body, the clavicle bone is the last to fuse and has various developmental levels, thus it is a valuable indicator of age at death during the post-pubertal period.

Using the clavicle for age estimation: The scoring methods

In 1924, Stevenson [15] was the earliest study on medial clavicular for the American group. Stevenson's findings were based on the collection of Hamann-Todd's study. He defined the beginning stage of the union from the age of 22 and completed union at age of 28 for all samples. He did not define any difference in the epiphyseal union between male and female.

Todd and D'Errico [16] conducted a large study on the medial and lateral clavicle epiphyses. They scored the clavicles based on 4 phases: phase 1 as no union, phase 2 as beginning union, phase 3 as a recent union with a scar, and finally phase 4 as complete union. They stated that unions are formed between 18 to 29 years of age. The ossifying centers start to unite from age 21 and the union would be completed around age 25. They did not mention any difference between sex and race in their study.

McKern and Stewart [17] released their study on epiphyseal union in 1950 based on the dead from the Korean war. Their report was based on a 5-phase scoring method. They added a phase to Todd and D' Errico's approach for active union: phase 1 for no union, phase 2 for beginning union, phase 3 for active union, phase 4 for recent union and phase 5 for completed union. They presented age 18 or early 17 for the beginning of union and age 25 for completed fusion. Their cases were selected from males hence they could not differentiate on sex.

Webb and Suchey [18] provided a standard reference of a modern sample for forensic purpose. Their study was based on 800 autopsy samples from Los Angeles in the 1970s. They scored the bones after extraction and cleaning. Their method was based on a 4-phase scoring method but was different from the previously mentioned method: phase 1 defined non-union with no epiphysis, phase 2 was for no union with separate epiphysis, phase 3 defined partial union and phase 4 was for complete union.

Phase 1 was continued to age 25 for males and age 23 for females, phase 2 was between age 16 to 22 years in males and between age 16 to 22 years in females, phase 3 was observed from 17 to 30 years in males and from 16 to 33 years in females, and the last phase from age 21 to 31 years in males and in females from age 20 to 34 years for complete fusion.

Black and Scheurer [19] introduced a 5-phase scoring approach for medial clavicular based on skeletons from the 18th century population in Lisbon. Their 5-phase scoring system was focused on non-union phases as shown in Figure1:

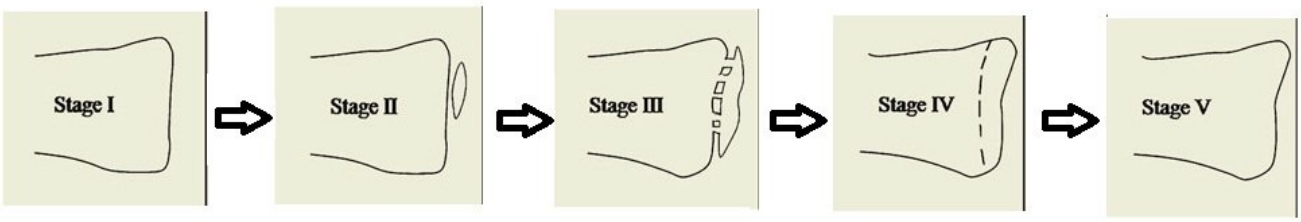
Phase 1: Ossification center in invisible (not yet ossified)

Phase 2: Ossification center is visible (no epiphyseal flake attached)

Phase 3: Growth plate is ossified, partially (flake commencing fusion)

Phase 4: Complete union of the epiphysis and metaphysis (fusion line is still visible)

Phase 5: Complete union (No trace of a fusion line)



Phase 1 was observed from 11 to 17 years, phase 2 from 15 to 22 years, phase 3 from 19 to 23 years, phase 4 was from 23 to 28 years, and phase 5 was 25+ years. The age ranges did not differentiate between the male and female samples because of small sample size.

In summary, the clavicle epiphysis has been presented as a useful and reliable indicator for skeletal age estimation in adults. Despite current research based on the different scoring methods, there is no standard scoring method that includes accepted error rate [20].

Conclusions

The clavicle as a long bone in human body has been used widely in both forensic practices and archaeological anthropology due to its ability to survive decay even after burial. Clavicle is a useful bone for skeletal age estimation especially for young adult subjects. This study reviews the different score-based methods used for age estimation based on the clavicle.In spite of various methods for age assessment using the clavicle, there is no standard scoring method with accepted accuracy.

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