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Age estimation by chest plate radiographs in a Thai male population

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ABSTRACT

Costal cartilage ossification on chest plate radiographs is one of the useful methods in age estimation for adults. This study was performed in 136 remains yielding a regression formula for age estimation in Thai male population. Eight features on chest plate imaging were scored based on Garvin's method. Composite scores were calculated by summation of all scores and analyzed to generate the regression of age as: Age = $16.664 \times e^{0.161\ (\text{composite score})}$ with a 95% prediction interval. The predicted age intervals in all composite scores were overlapping except for score 0 and 7. It could be concluded that if all features are absent/present, the person is likely to be less/more than 29 years old.

1. Introduction

Individual identification (ID) is crucial both in criminal and civil law and mass fatality management. According to the Interpol Disaster Victim Identification Guide [1], there are two methods of ID which are primary and secondary. Fingerprints, dental and genetic (DNA) profiles are primary identifiers in which only one item agreement can establish a positive ID. The other category is composed of secondary identifiers in which a combination of positive matches is needed for pronouncing ID. These identifiers are composed of body profile and personal effects. Body profile includes the basic data of the deceased which are race, gender, age and height, specific distinguishing features such as numbers on heart pacemakers or prosthesis and other medical findings such as scars, tattoo and disease etc. Though secondary criteria has a low potential for ID, it is beneficial in terms of making the group of missing persons to compare with the decedent smaller, resulting in a reduced time and cost of the process.

Age is one of body profile that is very effective in narrowing down the number of the missing persons to compare with the decedent's profile. Age estimation is quite easy to do when a body is complete. But, if the body is in a state of advanced decomposition or severely damaged, for example burned body, separated body parts, the age estimation needs to be performed on bones and teeth. Morphologic changes on the pubic symphysis and auricular surface, closure of cranial suture and changes of sternal rib ends have been well known for use as age estimation tools [2].

Radiographic analysis on skeletal maturation is one of the useful methods in age estimation, particularly hand and wrist imaging for estimating a child's age. After a person reaches subadult and adult ages, less body parts are useful for age estimation. Pattamapaspong et al. found computed tomography of the ossification of medial clavicular epiphysis was useful in age estimation in young adults [3]. For adults of advanced age, scoring of costal cartilage ossification on chest plate radiographs was first introduced for age estimation by McCormick in 1980 [4]. Later on, in 1989, Barres et al. [5] standardized the scoring method and applied it into a regression formula. However, the result had rather low correlation between score and chronological age. Recently, Garvin [6] created a practical method for age estimation in adults that could be used in both sex by observing eight features on chest plate radiographs and summarized them into a composite score which yielded a highly reliable chronological age estimate.

As far as electronic English language articles were reviewed, studying of age estimation by chest plate radiographs in the Mongoloid persons was not found. All researches were performed among Caucasians. According to differences in genetics and environment, Garvin's result which represents Caucasians may be unreliable with the Thai population.

The objective of this study was to generate a model for age estimation for the Thai male population by composite scoring of chest plate ossification based on Garvin's method.

2. Materials and methods

The study was approved by the Research Ethics Committee of the Faculty of Medicine, Chiang Mai University. Informed consent was not required. Chest plates, including manubria, sterna, clavicular ends, and

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rib ends, were removed from the male deceased who underwent autopsy at the Department of Forensic Medicine, Faculty of Medicine, Chiang Mai University. All of the deceased were Thai nationals, 15 years of age or older. The age and nationality was approved by Thai government identification documents. Any case with pathologic chest plate or injury at any site of the evaluated area was excluded. Duration of collecting samples started from January to June 2014. The age of the samples ranged from 15 to 81 years. The distribution was shown in Table 1. Most were in middle age group (Fig. 2).

Radiographs of all chest plates were performed in antero-posterior orientation with exposure parameters of 60 Kvps, 40 ma and 0.5 s. The images were evaluated on the Picture Archiving and Communication System (PACS). Standard viewing tools were used including invert color, brightness, zoom and contrast. Ossifications on images were evaluated regarding eight features, by using Garvin's method [6], by scoring ossification changed in 8 features as follow.

A Costal cartilage ossification of any of the sternal rib ends

B Costal cartilage ossification peri-sternally

C Costal cartilage ossification centri-chondrally (mid-costal cartilage)

D Irregularity or cartilage ossification to the costal manubrium notch

E Irregularity evidence of flaring, cupping, bony extensions, or bone degradation of the sternal rib ends

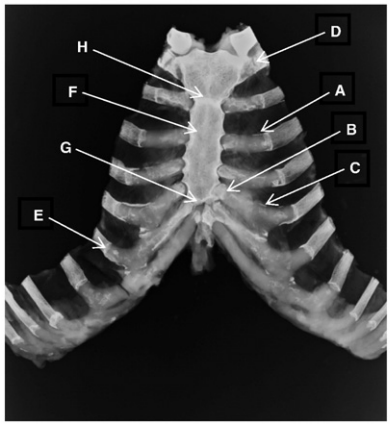
F Complete fusion of the sternal body

G Any bony fusion of the xiphoid to the sternal body

H Any bony fusion of the manubrium to the sternal body

Scoring was assigned as zero if the feature was absent and one if the feature was present. Then a composite score was calculated by summation of scores on all features, the example show in Fig. 1. Giving scores was performed by 2 forensic physicians. Verdict of score was done in scoring disagreement by consensus.

Descriptive statistics of age were presented as mean and standard deviations according to the scores of ossification appearance. Independent *t*-test was used to compare age averages between the scores. Regression analysis was performed on composite scores to generate the model for age prediction. To test the accuracy of method the equation was blinded tested with 29 unknown ages samples and accuracy within first standard error of estimation was calculated. The statistical significance was set at $p < 0.05$.



A Costal cartilage ossification of any of the sternal rib ends
B Costal cartilage ossification peri-sternally
C Costal cartilage ossification centri-chondrally (mid-costal cartilage)
D Irregularity or cartilage ossification to the costal manubrium notch
E Irregularity evidence of flaring, cupping, bony extensions, or bone degradation) of the sternal rib ends
F Complete fusion of the sternal body
G Any bony fusion of the xiphoid to the sternal body
H Any bony fusion of the manubrium to the sternal body

Fig. 1. Chest plate X-ray image and score; A = 1, B = 1, C = 1, D = 1, E = 1, F = 1, G = 0, H = 1. Composite score = 7 A Costal cartilage ossification of any of the sternal rib ends B Costal cartilage ossification peri-sternally C Costal cartilage ossification centri-chondrally (mid-costal cartilage) D Irregularity or cartilage ossification to the costal manubrium notch E Irregularity evidence of flaring, cupping, bony extensions, or bone degradation of the sternal rib ends F Complete fusion of the sternal body G Any bony fusion of the xiphoid to the sternal body H Any bony fusion of the manubrium to the sternal body

3. Results

The age of the samples ranged from 15 to 81 years. The distribution was shown in Table 1. Most were in middle age group (Fig. 2).

Descriptive analysis of the age according to the ossification appearance, which was score 0 (absent) and score 1 (present), in each feature was displayed in Table 2. Ossification in every feature was first observed in the imaging after 15 years old. The ones which were found early were costal cartilage ossification of the sternal rib ends and centri-chondrally (A, C), Irregularity of sternal rib end (E) and Complete fusion of the sternal body (F). While costal cartilage ossification peri-sternally (B), Irregularity or cartilage ossification to the costal manubrium notch (D), fusion of the xiphoid to the sternal body (G) and fusion of the manubrium to the sternal body (H), no such feature was present until in adult age. Maximal age of absent ossification change was in middle and late adult age in most features except irregularity of sternal rib end and complete fusion of the sternal body which found stay absent only until 24 years old.

Age average between score 0 and 1 was different in 4 features which were feature B ($p = 0.01$), D ($p = 0.04$), E ($p = 0.00$) and F ($p = 0.03$).

Table 1
Age distribution of samples included in the study.

Age (years)	Numbers
15–19	7
20–29	18
30–39	30
40–49	29
50–59	8
60–69	35
>70	9
Total	136

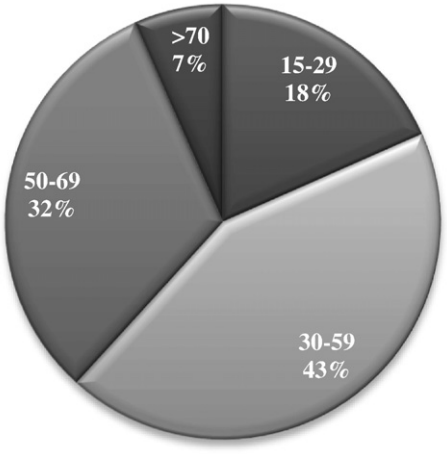


Fig. 2. Age group distribution of the samples.