Evaluation of the Relationship between Ossification of Sternal Joints and Age with Multi-Slice CT Scan

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Abstract

Objective: Sternum radiograph is used in determination of age after 21 years old according to manubriosternal body (MB) and xiphisternal joint body (XB) ossification. In this study, we intend to estimate age using multi-slice CT images as radiographs have lower sensitivity and CT images demonstrate ossification better.

Materials and Methods: Multi-slice thorax CT images found in PACS archive are evaluated retrospectively. Cases between 21-65 years old are selected. Coronal reconstruction images were obtained. MB and XB joint ossification presence and degree are evaluated in respective age groups. MB joint ossification is graded as 0-3 and XB joint ossification graded as 0-1. Relation between variables is examined with Spearman correlation coefficient. Threshold for age variable is calculated using ROC analysis.

Results: Multi-slice CT images of 396 cases are examined (198 females, 198 males). In females and males, MB and XB fusion was seen to start between age group of 21-25 years but there were complete fusion in a few. In 61-65 age groups there were cases without complete fusion. There was statistically significant difference in males and females according to MB and XB joint ossification in between age groups ($p<0.001$).

Conclution: Evaluation of MB and XB joint ossification with CT scan in age estimation is not appropriate between wide age groups.

***Key words*:** *Age estimation, sternum, ossification, CT.*

Introduction

Age of the individual has great influence on his social relations and judgements. Degree of ossification in the bones is defined as bone age and evaluated with comparison between the individuals in same age. In people with normal maturation of bone, bone age is same with chronological age [1,2]. In radiological studies, maturation of bony structures, ossification of epiphyseal lines and degree of fusion between joints are evaluated. Determination of bone age can be made with wrist radiograph between 0-16 or 18 years, pelvic radiograph between 17-22 years and shoulder radiograph to inspect clavicle medial end ossification between 18-24 years of age [3-4]. Especially after 25 years old, age determination is not very accurate and can be estimated in wide range of values. Recent studies are mostly centered on fusion of sacral and sternal distal ends and changes in vertebral-sternal ends of ribs [5-8]. Yet it is known there is no substantial data on alterations in the bones to determine bone age of individuals between 25-40 years and after 50 years old.

CT is sectional imaging method and has great advantage in contrast resolution compared to radiograph. In this study, our aim is to evaluate application of thin section CT images in determination of age between 21-65 years of age using manubriosternal body (MB) and xiphisternal joint body (XB) fusion grading system and to obtain regression formula in males and females.

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Materials and Methods

Case selection

The study protocol is approved by the Clinical Research Ethics Committee of the Uludag University Faculty of Medicine. Chest CT scans performed on 396 individuals aged between 21 and 65 years are evaluated retrospectively. The date of birth subtracted from the date of the CT scan was used to calculate an individual's chronological age in decimals (e.g., age 21 was defined as between the ages of 21.0 and 21.9). Patients with nutritional or endocrine disorders, constitutional growth retardation or cerebral palsy, chronic illness, developmental abnormalities, musculoskeletal disorders, artifacts due to motion or contrast medium, missing or doubtful data on chronological age, clavicular fracture and anatomic shape variants were excluded from the study. Radiologic assessment and data analysis in Multi-detector computed tomography (MDCT) studies were obtained using a 128-row MDCT system (Somatom Defination AS, Siemens Medical Solutions, Erlangen, Germany). Technical settings were 120 kV, reference mAs 120 using Care Dose, Pitch 1.0, collimation 0.6, recon increment 1.0, and sharp kernel settings. All scans were obtained from the patients in the supine position. The CT images were evaluated on screen using a workstation with BARCO software (General Electric). In work stations, 0,6 mm coronal reconstruction images were obtained from original 0,6 mm-thick axial images (MPR technique). Evaluation of fusion between joints is made using coronal reconstructed images.

For determination of age, MB and XB joints were carefully examined for degree of fusion. We evaluated the MB joint ossification with four-grade classification system formed by using the five-stage classification system described by Schmeling et al. (9) and the substages of stages 2 and 3 by Kellinghaus et al. [9]; (Figure 1).

Grade 0 - no fusion present in the joint.

Grade 1 -fusion present but less than half of joining surface.

Grade 2 -fusion present half or more than half of joining surface.

Grade 3 -complete fusion present.

We described two-grade classification system for evaluation of the XB joint fusion (Figure 2).

Grade 0 - no fusion present in the joint.

Grade 1 -complete fusion present.

Image Analysis

Two radiologists (GG as R1 and SC as R2) evaluated all of CT images. R1 had 15 years of professional experience in CT, and R2 had 5 years of experience. R1 also had experience with the musculoskeletal system. All cases are classified according to MB and XB joint fusion on the consensus of both radiologists. Prior to and during the image assessments, examiners were blinded to the age of the patients.

Statistical Analysis

The data is statistically analyzed for the relationship between fusion of joints and age of cases and regression equations were obtained, separately for males and females. Statistical analysis of data is made using SPSS 23.0 statistical package software. Kruskal-Wallis test is used for comparison of more than two groups for data doesn't have normal distribution. Pearson Chi-Square test is used for categorical variables. Dunn test from multi-comparison tests is used for significant results. Significance level is set as α=0.05.

Results

396 cases in total were included in study. There were 198 males and 198 females. The subjects were divided into groups on the basis of their age and sex. Age groups were formed as 21-25, 26-30, 31-35, 36-40, 41- 45. 46-50, 51-55, 56-60, 61-65 years. There were nine groups with 44 cases and in each group males' and females' number were same (22 females, 22 males).

In females and males, it was observed that MB and XB joint fusion is initiated in age group of 21-25 years. In 21-25 age group a female and five males had complete fusion in XB joint and in more than 60 years' age group three females hadn't complete fusion. In males a case hadn't complete fusion in XB joint in groups of more than 50 years of age. In MB joint we detected that fusion starts at 21-25 age group (grade 1), there were a few cases with complete fusion in 26-30 age group (grade 3). In some cases in more than 60 years' age group there

wasn't complete fusion and in some fusion even haven't begun (grade 0); (Figure 3,4,5).

In MB joint, we detected 122 grade 0 (%61.6), 30 grade 1 (%15.2), 7 grade 2 (%3.5) and 39 grade 3 (%19.7) fusion in females. In males we detected 135 grade 0 (%68.2), 25 grade 1 (%12.6), 10 grade 2 (%5.1) and 28 grade 3 (%14.1) fusion (Table 1).

In XB joint, we detected 67 grade 0 (%61.6), 131 grade 1 (%15.2) fusion in females. In males we detected 64 grade 0 (%32.3), 134 grade 1 (%67.7) fusion (Table 2).

In males and females there was statistically significant difference in MB joint ossification between some age groups (p=0.004, p=0.001; respectively). In females, MB joint ossification grade of 61-65 age group is more than 21-25 age group (p=0,037). In males, there was significant difference between 21-25 age group and 31-35 (p=0,020), 56-60 (p=0,008), 61-65 (p=0,002) age groups. 21-25 age group males have less MB joint ossification grade than other age groups.

In males and females there was statistically significant difference in XB joint ossification between some age groups (p<0.001 in both). XB joint fusion is more likely in females with more than 46-50 age group. In males despite there is significant difference between some age groups, there is too much overlapping between fusion grade of the age groups. Therefore it can't be said there is more probability of fusion in between some age groups.

In our study there was significant difference in males and females when MB and XB joint ossification compared between age groups together (p<0.001). ROC analysis is made for MB joint fusion and in females 41 years is assigned as cut-off value with %69.74 sensitivity and %56.56 specificity, in males 30 years is assigned as cut-off value with %93.65 sensitivity and %29.63 specificity. For XB joint fusion in females 43 years is assigned as cut-off value with %66.6 sensitivity and %85.1 specificity using ROC analysis, in males 41 years is assigned as cut-off value with %71.64 sensitivity and %84.37 specificity (Table 3).

Table 1. MB joint ossification

Age groups	Female-MB ossification grade				Total	Male-MB ossification grade				Total
	Grade 0	Grade 1	Grade 2	Grade 3		Grade 0	Grade 1	Grade 2	Grade 3	
21-25	19	3	0	0	22	22	0	0	0	22
26-30	11	3	3	5	22	18	1	1	2	22
31-35	18	2	0	2	22	10	3	2	7	22
36-40	17	3	1	1	22	17	2	2	1	22
41-45	12	3	1	6	22	14	5	1	2	22
46-50	14	3	0	5	22	17	1	1	3	22
51-55	12	3	1	6	22	16	2	1	3	22
56-60	11	2	1	8	22	10	6	1	5	22
61-65	8	8	0	6	22	11	5	1	5	22
Total	122	30	7	39	198	135	25	10	28	198

Table 2. XB joint ossification

Age groups	Female			Male		
	XB ossification grade		Total	XB ossification grade		Total
	Grade 0	Grade 1		Grade 0	Grade 1	
21-25	21	1	22	17	5	22
26-30	13	9	22	14	8	22
31-35	9	13	22	12	10	22
36-40	6	16	22	9	13	22
41-45	10	12	22	6	16	22
46-50	2	20	22	5	17	22
51-55	1	21	22	0	22	22
56-60	2	20	22	1	21	22
61-65	3	19	22	0	22	22
Total	67	131	198	64	134	198

Table 3. ROC analysis results.

XB joint	Cut-off age	Sensitivity	Specificity	AUC value	P value
Whole groups	43	66,42(60,4-72,1)	83,26(79,2-91-6)	0,835	<0.001
Female	43	65,6(56,9-73,7)	85,1(74,3-92,6)	0,817	<0.001
Male	41	71,64(63,2-79,1)	84,37(73,1-92,2)	0,851	<0.001
MB joint	Cut-off age	Sensitivity	Specificity	AUC value	P value
Whole groups	41	67,63(59,2-75,3)	54,09(47,8-60,3)	0,641	<0.001
Female	41	69,74(58,1-79,8)	56,56(47,3-65,5)	0.636	<0.001
Male	30	93,65(84,5-98,2)	29,63(22,1-38,1)	0,650	<0.001

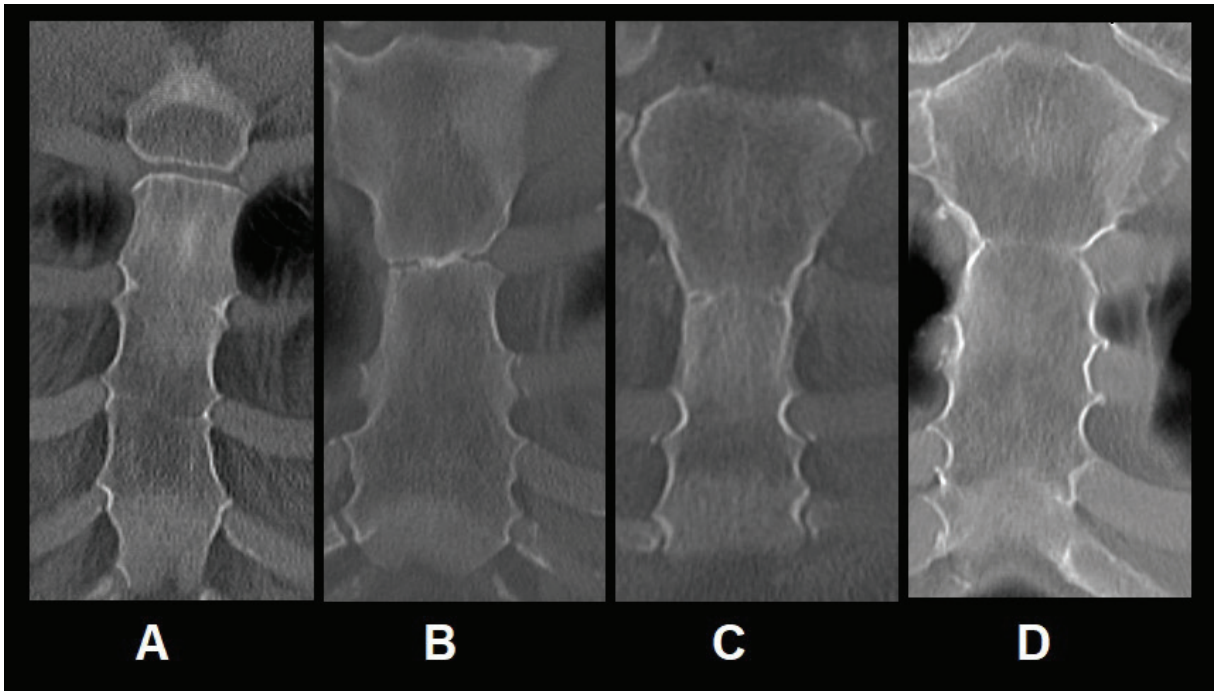

Figure 1 - MB joint fusion four-stage classification system. Grade 0 - no fusion present in the joint (A). Grade 1 - fusion present but less than half of joining surface (B). Grade 2 - fusion present half or more than half of joining surface (C). Grade 3 - complete fusion present (D).

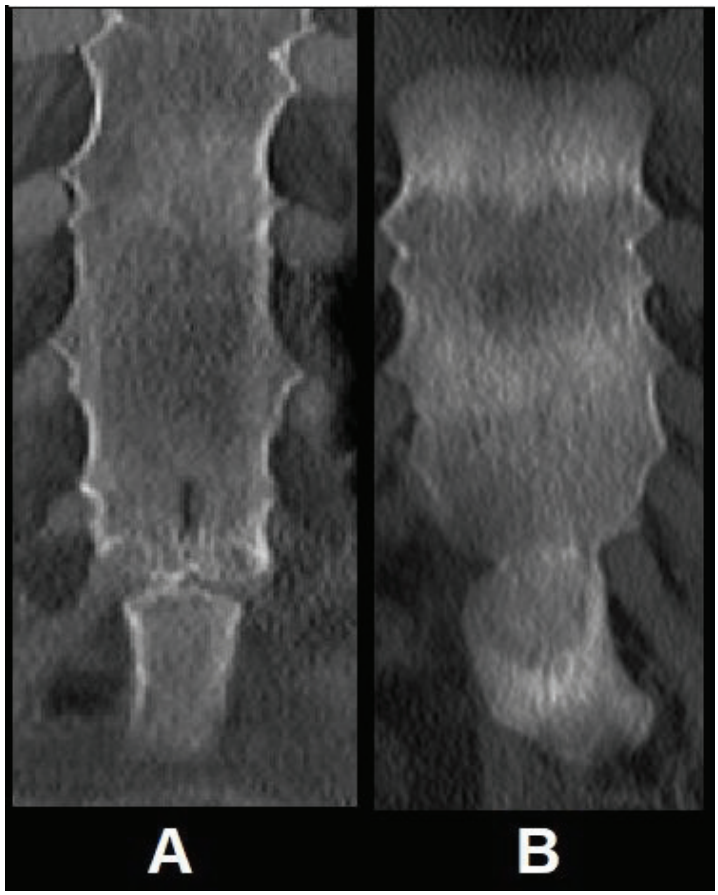

Figure 2 – XB joint fusion classification. Grade 0 - no fusion present in the joint (A). Grade 1 - complete fusion present (B).

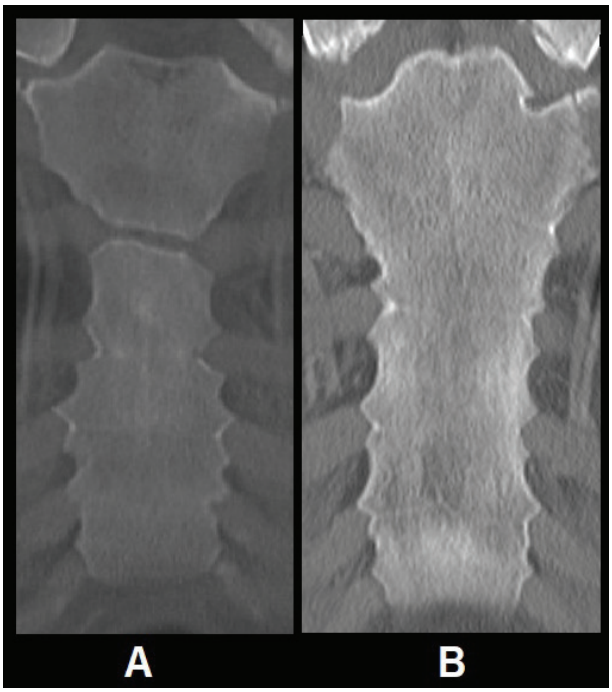

Figure 3 – At 21-25 age group there can be seen grade 0 (A) and grade 3 (B) fusion at MB joint.

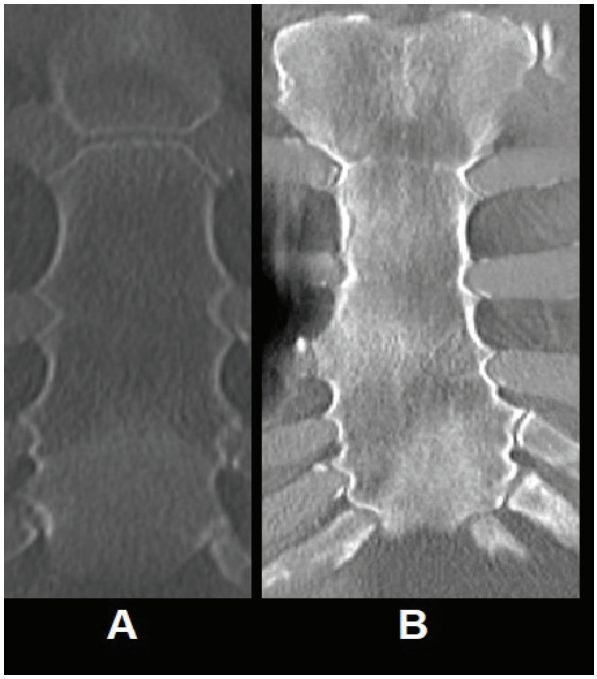

Figure 4 – At 61-65 age group there can be seen grade 0 (A) and grade 3 (B) fusion at MB joint.

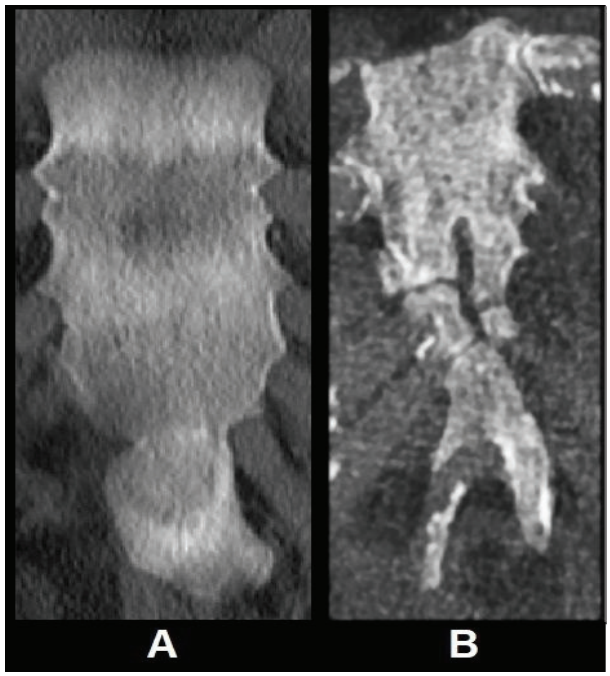

Figure 5 – At 21-25 age group there are patients with grade 1 fusion (A) and at 61-65 age group even patients with grade 0 fusion (B) could be detected.

Discussion

Radiological evaluation utilizing radiographs of certain bony structures are mostly used methods in determination of age. Lateral sacrum and coccyx radiograph is used between 23-40 years and lateral sternum radiograph around 40 years. Sternum has been studied by very few authors regarding its utility for estimation of age [6,7,10-18]. Authors have described fusion of xiphoid process with mesosternum at about 40 years of age and that of manubrium with mesosternum at "Very old age" i.e. 55-60 years [12]. Forensic medicine experts usually base their opinion on these observations. After 50 years old, fusion between manubrium and corpus is accepted as completed. For this reason, in our study we used sectional imaging method CT to evaluate accuracy of these methods. Our aim is to investigate utilizing MB and XB joint ossification grade as a method in determination of age.

In 1934 Trotter M [16], described the lack of a correlation of the manubriosternal junction fusion with age. Bacci N et al [17], the majority of sterna remain unfused throughout adult life, with complete fusion observed both in young and old individuals. In our study we found that there is no fusion and even ossification of MB joint in 21-25 years age group. In our study we

detected 4 cases in females and 2 cases in males with grade 3 ossification (fusion) in age groups less than 30 years. We found there wasn't ossification in 8 cases of females (%36.4) and 11 cases of males (%50) in more than 60 years' age groups. Despite there is significant difference of MB joint ossificiation in some age groups in males and females, utilizing MB joint in age estimation is not appropriate due to differences in ossification grades between each groups and excessive overlapping in wide age groups. It can be utilized in distinguishing young and elder population yet it is not our main aim and not convenient in clinical practice either.

According to Susan Standring et al [18], xiphisternal joint is usually transformed to synostosis by the 40 years and sometimes remains unchanged even in old age. In our study we detected cases with XB joint fusion in 21-25 years. There were 7 cases (%17.1) in females and 12 cases (%30) in males with grade 1 ossification (fusion) under 30 years old. 6 cases in females and a case in males greater than 50 years old had not ossification in XB joint (grade 0). Therefore, using XB joint in age estimation with CT scan is not appropriate in wide age groups.

There are several limitations in our study. Mainly determination of age using sternal joints is affected by geographic, ethnical, genetic, socioeconomic factors, nutritional habits besides diseases. Secondly due to investigation of wide age groups there is substantial overlapping in joint ossifications. That makes separation of age groups according to ossification more difficult. Thirdly there were fewer cases in each group after forming age groups. Our study can be repeated with more people and in closer age groups.

As a conclusion, sternal ossification can be evaluated well with thin section CT images. But it is arduous to estimate age in wide age groups using MB and XB joint ossification. As in earlier ages ossification can be detected, on the contrary in older ages there couldn't be any ossification. Despite there are statistically significant differences between some age groups, as there is no major differences CT is not convenient in age estimation. Only it can be said that XB joint fusion is seen more after 40 years. It should be reinforced with new studies in a greater number of population.

For Ethical Statement: Compliance with Ethical Standards

Funding: No

Conflict of Interest: No

Ethical approval: Yes

Informed consent: No (because retrospective study)

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