Computed tomography-based age estimation of iliac crests calcification in 10-29 year-old individuals
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ABSTRACT

Introduction: Estimating the age of the ossification of the iliac crest may help determine the legal age. For this purpose, both anthropological and radiological methods (conventional radiography, ultrasound, Tomography, and MRI) have been used to study different systems. Objectives: The present study aimed to to evaluate the iliac crest apophysis for age estimation through multidetector computed tomography (MDCT) in 10- to 29-year-old individuals. Materials and Methods: This retrospective study was carried out on 10- to 29-year-old individuals who underwent pelvic CT examinations for different reasons in Imam Khomeini and Golestan hospitals of Ahwaz during 2016-2018. The CT examinations of the iliac crest apophysis of 531 patients (267 females and 264 males) were evaluated based on the Kreitner's four-stage system. Results: According to the Kreitner's four-stage system, the minimum age for both sides of the pelvis at stage 2 for girls and boys was 12 years and 13 years, respectively. However, at stage 3, the minimum age for girls and boys was 15 and 17 years, respectively. Accordingly, stage 4 was first observed in boys at age 17 on both sides of the pelvis. In contrast, it appeared in girls at the age of 20 on the right side. Conclusion: Along with the findings of other studies, the results showed that multidetector computed tomography (MDCT) is recommended for iliac crest in retrospective cases (where pelvic CT scans already exist), and it may be considered as a supportive method for age-estimation purposes. Moreover, when CT images are used along with other age estimation methods, they provide physicians with valuable supplementary information.

Keywords: Age estimation, iliac crest apophysis, Kreitner's staging system, multidetector computed tomography

Introduction

Today, it is important to determine the true age of individuals in radiology and forensic medicine.¹,² The legal age of adolescents and young people is an important issue in civil, criminal, and immigration law.³,⁴ Moreover, in forensic medicine, it is important to determine the exact age of individuals (in terms of age range). According to the liability definition specified in each country, children and adolescents lack legal liability for committing a crime within a certain age range. They are treated differently from adolescents and adults. Accordingly, the way judiciary treats them is important as well.²,⁵

Currently, modern radiological studies are easily accessible and accurate. It is possible to investigate the details of apophysis through tomography by evaluating the clavicle ossification.⁶,⁷ According to the Study Group on Forensic Age Diagnostics (AGFAD), the radiological evaluation of the left hand, teeth, or clavicle is used to determine the actual age, provided that hand ossification is complete.²,⁵,⁷,⁸,⁹,¹⁰,¹¹,¹²

The process of evolution or ossification of the iliac crest in the pelvis in the pelvis occurs at a relatively late in human developmental stages. Therefore, iliac crest is an important anatomical region which can be used to determine the age of the individuals. The bone is also used in conjunction with clavicle and bone elements of the hand to determine the true age of the individuals.¹,² The histomorphometric changes in bone reconstruction and bone changes are investigated using iliac crest.
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Hence, it is useful to evaluate the process of ossification and fusion of this bone from the pelvis.

For the first time, Risser introduced a staging system for ossification of the iliac crest in the prognostic follow-up of patients with ideoplastic sclerosis. This staging system is known as the Risser Sign which is used physicians to monitor patients with ideoplastic sclerosis (French and American versions).

In previous studies, ultrasound, MRI and tomography were used to determine the legal age based on the ossification of the iliac crest. However, these studies have used different methods to evaluate the bone age and there is no standardized method for age determination.

Despite increased radiation, computed tomography is very valuable due to multi-slice and multi-planar imaging and lack of superimpositions. However, computed tomography should only be used in cases where other methods are not effective.

Although many studies have investigated the role of clavicle CT in determining the legal age of individuals, this method has been widely accepted for evaluating the bone age. Regarding the use of this modality in determining the legal age, few studies have been carried out using iliac crest apophysis. Further studies are required to investigate the iliac crest apophysis.

There are different staging methods for determining the legal age using medial clavicular apophysis calcification, including Kreitner’s four-stage criteria, Risser’s 5-stage criteria, the 7-stage MSCT modified scoring criteria, Cameriere’s criteria and Schmeling’s 5-stage method. Although Kreitner’s criteria appear to be easier to use and produce reliable results, few studies have used the four-stage criteria for estimating iliac crest.

Therefore, the present study aimed to determine the legal age using Multidetector Computed Tomography and Kreitner’s four-stage criteria.

Materials and Methods

This retrospective cross-sectional study aimed to determine the bone age based on iliac crest calcification in CT scan images using Kreitner’s four-stage criteria. This study was approved by the Ethics Committee of Ahvaz Jundishapur University of Medical Sciences (IR.AJUMS.REC.2018.385). In this study, 531 patients aged 10–29 years of age were diagnosed with symptoms such as trauma, abdominal pain, etc. The exclusion criteria included the metabolic diseases that interact with growth process, iliac crest pathology such as fractures, bone prostheses, and mass and error in CT images. These errors may interfere with the evaluation.

All CT scans were performed using a multiple detector tomography device (Siemens; Germany) with 16 slices at 120–130 kVp and automatic tube modulation at 60–220 mA. Raw data were reconstructed using bone algorithms. All CT scans were evaluated by an experienced radiologist who did not know the age of the patients.

Evaluating the ossification process

Kreitner’s four-stage criteria was used to evaluate the ossification of the iliac crest apophysis. Stage 1 = ossification center has not ossified yet [See Figure 1]
Stage 2 = ossification center has ossified, apophyseal cartilage has not ossified [See Figure 2]
Stage 3 = apophyseal cartilage has partially ossified [See Figure 3]
Stage 4 = apophyseal cartilage has fully ossified [See Figure 4].

Data analysis

SPSS (version 22) was used to analyze the data. Accordingly, Spearman Correlation Analysis was used to investigate the relationship between age and stage of iliac crest ossification. The significance level (P value) was 0.05.

Results

In this study, the pelvis CT scans of 531 patients were evaluated. Accordingly, 267 (50.3%) girls and 264 (49.7%) boys aged 10–29 years old participated in the study. The mean age of the subjects was 22.93 ± 4.85 years. There was no significant difference between the age of both male and female patients (P = 0.113).

Tables 1 and 2 show the mean, standard deviation, maximum, minimum, median, and median in different stages of iliac crest ossification based on Kreitner’s. According to this criterion, the minimum age for both sides of the pelvis at stage 2 was 12 years and 13 years for girls and boys, respectively. However, at stage 3, the minimum age was 15 years and 17 years for girls and boys, respectively. Stage 4 was first observed in boys on both sides.

Figure 1: Sectional CT axial image of stage 1: The ossification center has not clinically ossified yet
Comparison of CT results on both sides of the pelvis showed that there was a significant difference between the right and left iliac crests in 49 patients (31 males and 18 males) ($P = 0.001$).

Spearman Correlation Analysis showed a positive significant correlation between age and iliac crest ossification ($P = 0.0001$; boys: right side, $r = 0.719$, left side, $r = 0.716$; $P = 0.0001$, girls: right side, $0.724$, left side, $r = 0.700$; $P = 0.0001$).

**Discussion**

According to this criterion, the minimum age for both sides of the pelvis at stage 2 was 12 years and 13 years for girls and boys, respectively. However, at stage 3, the minimum age was 15 years and 17 years for girls and boys, respectively. Stage 4 was first observed in boys on both sides of the pelvis at age 17. Stage 4 was first observed in boys on both sides of the pelvis at age 17. However, it was detected in girls on the right at the age of 20.
Regarding the evaluation of iliac crest apophysis, the results of this study are comparable to those of other studies. However, direct comparison of data is not possible in studies with different methodologies. This is mainly because different radiological techniques have been used by different individuals.

Similarly, Ekizoglu et al. (2016) used Kreinter’s four-stage system in order to evaluate the iliac crest apophysis in CT images. In this study, the minimum age for both genders on both sides of the pelvis at stages 2 and 3 was 12 and 14 years, respectively. In stage 4, the minimum age at the right of the pelvis was 17 years in both genders. However, the minimum age at the left side of the pelvis for girls and boys was 18 years and 17 years, respectively.[9] These results are in good agreement with those of the present study. This study showed that the determination of bone age with Kreinter’s criteria is possible in girls up to the age of 18–20 years. This difference can be attributed to the different experiences of those who review the images.

Albayrak et al. determined the bone age in CT images using Schmeling’s 5-stage method. The results of their study indicated that the minimum age at stage 5 was 18 in both genders. The minimum age at stages 2, 3 and 4 was 12, 15, and 20 years, respectively. These results are similar to stages 2, 3 and 4 in the present study. Given the fact that this study did not include stage 5, the results of stage 5 are not comparable.[11]

Wittschieber et al.[12] evaluated the iliac crest apophysis using Kreinter’s four-stage criteria. In addition to the four-stage criteria, they also evaluated the subgroups of stages 2 and 3. They showed that the first identifiable age at stage 2 in both genders was 12 years. However, at stage 4, the minimum age for girls and boys was 16 and 17, respectively. Moreover, the minimum age at stage 3 for girls and boys was 13 and 14, respectively. They argued that simple radiography is not reliable, because projection artifacts conceal the posterior iliac crest. For this purpose, cross-sectional imaging techniques such as CT and MRI can help prevent these artifacts. The results of stage 2 in girls and stage 4 in boys are similar to the present study. However, the results are completely different at stage 3 because the minimum age at stage 3 in the present study was 15 and 17 years. This difference seems to result from the differences in the imaging method, the difference in the socioeconomic status of the samples, as well as the different experiences of the evaluators of the iliac crest CT images in two studies.

Unlike conventional methods, CT images were not affected by projection artifacts, superimposition of external materials and intestinal loops. On the other hand, limited information was available on the socioeconomic status of the subject. This can affect the bone development process. Therefore, this problem should be taken into consideration, especially for comparing the results of this study with those of Wittschieber et al.[12,13] Moreover, the results of iliac crest CT images taken with different methods need to be paid attention. [27,28] According to the US classification system, Germany and Turkey ranked fourth and 69th in terms of socioeconomic index, respectively.[29] This difference can affect the results and can explain the contradictions. Additionally, this method is strongly influenced by the experiences of those who review the images. It should be noted that the reliability of age determination methods may be influenced by the observer’s experience.[30]

Owings-Webb and Myers-Suchery[31] investigated the iliac crest in 605 men and 245 women using a four-stage system. They showed that the minimum age for complete anterior iliac wing calcification was 17 years and 18 years in men and women, respectively. These results are in good agreement with those of the present study.

Wittschieber et al.[32] examined similar limitations for iliac crest classification based on MRI and found that classification of the subgroups is not feasible. Wittschieber et al.[33] argued that complex anatomy, movement artifacts, surrounding structures, and low-resolution images make the evaluation impossible. Although CT has the advantages of bone evaluation compared to MRI, this cannot help determine the length of the iliac wing. Although it is important to evaluate the minimum age for each stage, the maximum age is also important.

In the present study, the maximum age at stage 2 on both sides in girls and boys was 25 years and 26 years, respectively. However, at stages 3 and 4, the maximum age on both sides and in both genders was 29 years. In this study, the age range at stage 1-3 on both sides of the iliac crest varied from 10 to 29 years. Accordingly, at stage 4, the maximum age was 29 years.

There are differences between the results of various studies which can be attributed to the use of different staging systems and the socioeconomic and ethnic differences of the subjects. Previous studies reported that socioeconomic factors affect bone development and growth. Accordingly, skeletal development in poor socioeconomic conditions is delayed.[31,32] Thus, further investigations are required into different populations to understand these differences.

Investigating the iliac crest in CT images has many advantages over conventional methods, including prevention of intestinal gas-induced superimposition, foreign objects, decrease in the superposition between apophysis and iliac bones and multiplanar capability. On the other hand, the main disadvantages of CT evaluation are the relatively high level of radiation, especially gonadal exposure, compared with conventional radiography. It is unlikely to use CT for prospective iliac morphology studies.[33] However, the protective shields can slightly reduce the dose of radiation during pelvic scans.[29]

On the other hand, the advantages of wrist radiographies include low radiation, easy utility, low cost, and high reliability. Therefore, since hand and wrist radiographies and medial clavicular studies provide valuable information for determining bone age,[34] the evaluation of iliac crest apophysis using CT can confirm the
imaging methods. The evaluation of iliac crest apophysis is a supportive tool for those who have taken pelvic CT images for a variety of clinical cases.

**Conclusion**

The results indicated that multi-detector computed tomography (CT) is a useful method for determining legal age. This method is also recommended for skeptical cases. When CT images are used along with other bone evaluation methods, they provide supplementary and validating information for physicians. However, due to limited studies in this area, it is not possible to make a definitive decision on the choice of a standard bone age estimation/evaluation method.

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**Conflicts of interest**

There are no conflicts of interest.

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