Forensic Age Estimation Through Sonographic Evaluation of Apophyseal Ossification of the Iliac Crest Among Egyptian Subjects

KHALED M. EL-GERBY, M.D.*; AZZA S. MOHAMMED, M.D.** and MIE S.GOMAA, M.D.**

The Departments of Radiodiagnosis* and Forensic Medicine & Toxicology**, Faculty of Medicine, Zagazig University

Abstract

Background and Aim: Forensic age estimation of living individuals is a recent focus of scientific interest. Ultrasonographic examination of the hip is a safe and cost-effective method for assessment of skeletal age. Ultrasonography of the iliac bone apophysis and distal radial epiphysis is a useful and highly acceptable tool for bone age determination. The purpose of this study was to determine the forensic applicability of ultrasound evaluation of the apophyseal ossification of the iliac crest among Egyptian subject for age assessment.

Subjects and Methods: The study was carried out on sonographic images of iliac crests of 110 Egyptian subjects (45 females and 65 males, age range: 10-23 years). The individual stage of apophyseal ossification of the left iliac crest was determined with reference to the definition of the four stages of clavicular ossification according to Schulz et al.

Results: The mean values of the subjects’ chronological age increase with progressive ossification stage. The minimum age for ossification stage I was 13.6 years in boys; ossification stage I could not be established in any of the female subjects of this study group. The earliest observation of ossification stage II was at a chronological age of 14.3 years in males and 11.5 years in females. Ossification stage III first occurred at the age of 16.4 years in males and 15.4 years in females. The earliest age of occurrence of ossification stage IV was at least 18.2 years in males and at least 17.3 years in females.

Conclusion: Sonographic examination of the iliac crest apophysis can become established as a valid and efficient method for forensic age diagnostics in living individuals.

Key Words: Forensic age estimation – Bone age Iliac crest – Sonography

Introduction

ESTIMATING the age-at-death of adult skeletal remains is one of the most important and most difficult aspects of forensic anthropological analysis. The methods for estimating age in adult skeletal individuals are based on morphological and degenerative changes in bones and teeth throughout life. The rate and degree of change are determined by a complex set of interactions among genes, culture, and environment that contribute to each individual life history [1-3].

The key to the successful application of a particular method is an understanding of whether the method is accurate (correct), precise (refined), and repeatable from an intra- and interobserver standpoint when applied to unknown individuals outside of the original reference sample [4-9].

In contexts of criminal law, this process of age estimation will help to determine whether individuals without valid identity papers have reached the age of criminal responsibility and whether juvenile criminal law is applicable. In civil guardianship and trusteeship matters, as well as in questions concerning the right of asylum of victims of political persecution, where the age of the individuals concerned is not proven, there is a need to investigate whether the relevant age limits have been exceeded [10,11].

As the chronologic age of the patient is assumed to be inaccurate [12,13] several parameters have been proposed in maturity determination, such as the rib apophysis, timing of menarche, peak height velocity, assessment of the olecranon, calendared skeletal age of the hand or wrist, the Risser sign, and electromyography [14,15].

In the field of clinical orthopedics, determination of the maturation stage of the apophyseal iliac crest to identify the so-called Risser sign has long been established and can be referred to as a standard instrument for bone age determination [11,16]. Risser described six grades from Risser 0 (no apophysis visible) through Risser 5 (fusion of the apophysis to the ilium). Risser 1 is 25% excursion, Risser 2,50% excursion, Risser 3,75% and Risser
4 is complete excursion. Risser Grade determination is a simple and readily available method and therefore it is frequently used. However, radiation exposure is a significant problem in these young persons. A reduction of the radiation dose may be achieved by using ultrasound devices to estimate the skeletal age [18].

The purpose of this study was to determine the applicability of ultrasound evaluation of the apophyseal ossification of the iliac crest among Egyptian subject for age assessment.

**Subjects and Methods**

This study was performed on 110 patients (65 males & 45 females) children, adolescents and adults, aged between 10-23 years who had been subjected to ultrasound examinations for various clinical reasons. The cases were explored at multiple abdominal and pelvic sites in the Radiology department of Zagazig University Hospital in the period between June to 31st December 2011. All subjects were free of any signs of pelvic skeletal pathology such as fracture, inflammation, cysts of tumors. Subjects with those pathologies were excluded from the study. All subjects or their legal guardians gave their informed consent for the performance of the examination. The ultrasound examinations were performed using a (Pro Focus GE ultrasound LOGIO 3 USA equipped with an 8-MHz linear transducer). In prone position, it was possible to scan the apophysis of the iliac crest in all subjects by parallel translation of the transducer in the longitudinal sectional plane setting along its full anterolateral-posteromedial segment. The study results were reached by an examiner certified in the field of skeletal sonography who did not know the subjects’ chronological age. Corresponding to the constellation of the sonomorphological findings, the ossification stage of the apophyseal iliac crest was determined with reference to the definition of the four stages of clavicular ossification according to Schulz et al. [19].

- **Stage I:** The upper margin of the iliac crest is configured at an acute angle. A secondary ossification centre (apophysis) is not educible in the entire region under examination.

- **Stage II:** The upper margin of the iliac crest is separated from a secondary ossification centre (apophysis) by an ultrasound gap in the entire region under examination.

- **Stage III:** Both section planes with an ultrasound gap between the upper margin of the iliac crest and the secondary ossification centre (apophysis), as well as section planes with a convex curve of the upper margin of the iliac crest without a separate ossification centre (apophysis), are educible in the region under examination.

- **Stage IV:** The upper margin of the iliac crest presents a convex curve in the entire region under examination. A separate ossification centre is not definable.

Fig. (1) shows the diagram of the sonomorphological staging of apophyseal ossification of the iliac crest.

The sonograms in Figs. (2,3) show the characteristic sonomorphological findings of stages (II and IV).

<table>
<thead>
<tr>
<th>Chronological age (years)</th>
<th>Female</th>
<th>Male</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>3</td>
<td>3</td>
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<tr>
<td>12</td>
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<td>13</td>
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<td>15</td>
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<td>16</td>
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<td>1</td>
<td>2</td>
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<tr>
<td>20</td>
<td>5</td>
<td>1</td>
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<tr>
<td>21</td>
<td>3</td>
<td>4</td>
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<td>22</td>
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<tr>
<td>23</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>E</td>
<td>45</td>
<td>65</td>
</tr>
</tbody>
</table>

Fig. (1): Diagram of the sonomorphological staging of apophyseal ossification of the iliac crest.
Figs. (2,3): Sonogmorphological findings of ossification stages II and IV of the iliac crest apophysis.

Statistical analysis:
Statistical analysis was done by using SPSS 10.1 software program. Statistical significance between two means was assessed by student’s $t$-test at $p<0.05$.

Results

Classification of the respective sonographic ossification stage of the iliac crest apophysis was possible in all 110 of the examined cases. (Table 2): Shows the minimum and maximum ages, as well as the calculated mean values and standard deviations of the ages of apophyseal ossification of iliac crest in both sexes through stages I to IV. According to this, the mean values of the subjects’ chronological age increase with progressive ossification stage. The minimum age for ossification stage I was 13.6 years in boys; ossification stage I could not be established in any of the female subjects of this study group. The earliest observation of ossification stage II was at a chronological age of 14.3 years in males and 11.5 years in females. A comparison between male and female data revealed statistically significant differences for stage II ($p<0.05$) with the female subjects achieving that stage on average 30 months earlier than the male subjects (Table 3). Ossification stage III first occurred at the age of 16.4 years in males and 15.4 years in females. The earliest age of occurrence of ossification stage IV was at least 18.2 years in males and at least 17.3 years in females (Figs. 1,2,3 & Table 2). For stages III and, IV no statistically significant differences between the sexes were observed (Table 3).

Table (2): Minimum and maximum ages, as well as the calculated mean values and standard deviations of the ages of apophyseal ossification of iliac crest in both sexes through stages I to IV.

<table>
<thead>
<tr>
<th>Ossification stage</th>
<th>No. of cases</th>
<th>Min, max (years)</th>
<th>Mean±SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stage I:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>10</td>
<td>13.6-15.2</td>
<td>14.3±0.63</td>
</tr>
<tr>
<td>Female</td>
<td>0</td>
<td>0-0</td>
<td>0.0±0.0</td>
</tr>
<tr>
<td>Stage II:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>26</td>
<td>14.3-21.4</td>
<td>17±2.1</td>
</tr>
<tr>
<td>Female</td>
<td>16</td>
<td>11.5-17.6</td>
<td>14.6±2.0</td>
</tr>
<tr>
<td>Stage III:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>19</td>
<td>16.4-18.6</td>
<td>17.7±0.7</td>
</tr>
<tr>
<td>Female</td>
<td>15</td>
<td>15.4-21</td>
<td>17.4±1.9</td>
</tr>
<tr>
<td>Stage IV:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>10</td>
<td>18.2-18.9</td>
<td>18.6±0.3</td>
</tr>
<tr>
<td>Female</td>
<td>14</td>
<td>17.3-22.9</td>
<td>17.1±1.6</td>
</tr>
</tbody>
</table>

Table (3): Statistical comparison of mean values and standard deviations of the ages of apophyseal ossification of iliac crest in male and female through stages I to IV.

<table>
<thead>
<tr>
<th>Ossification stage</th>
<th>Male Mean±SD</th>
<th>Female Mean±SD</th>
<th>$t$-test</th>
<th>$p$-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stage I</td>
<td>14.3±0.63</td>
<td>0.0±0.00</td>
<td>&lt;0.05</td>
<td></td>
</tr>
<tr>
<td>Stage II</td>
<td>17±2.1</td>
<td>14.6±2.0</td>
<td>&lt;0.05</td>
<td></td>
</tr>
<tr>
<td>Stage III</td>
<td>17.7±0.7</td>
<td>17.4±1.9</td>
<td>&gt;0.05</td>
<td></td>
</tr>
<tr>
<td>Stage IV</td>
<td>18.6±0.3</td>
<td>17.1±1.6</td>
<td>&gt;0.05</td>
<td></td>
</tr>
</tbody>
</table>

Discussion

Forensic age estimation of living individuals is a recent focus of scientific interest [20-26]. Skeletal maturity can be considered to be the most important indicator of growth and differentiation processes of the human organism as a whole. In the course
of ontogenesis, the genetically determined matura-
tion sequences of the various skeletal elements
occur with great regularity within a certain variation
range [27,28]. This chronological dependency of
skeletal development is therefore an essential basis
for clinical and forensic estimation of the age of
the individual. There are very close relationships
between the maturation processes of different parts
of the human skeletal system [29]. For this reason,
the stage of maturity of individual defined skeletal
elements can be interpreted as a manifestation of
general skeletal maturity. The majority of authors
see a reliable maturity indicator in the developmen-
tal progress of the iliac crest apophysis. In this
context, the ossification process of the iliac crest
apophysis was also analyzed dependent on the
skeletal age of the hand according to Greulich and
Pyle, as well as on chronological age [30]. The
ultrasonographic version of the Greulich-Pyle atlas
can be used to estimate bone age even in ultra-
sonography departments. This method is highly
correlated and a valid alternative to plain radiog-
raphy for bone age estimation. This enables esti-
mation of skeletal age in ultrasonography depart-
ments easily without exposing the patient to
radiation [31].

Ultrasoundography is a rapidly evolving technique
that is gaining popularity for the evaluation and
treatment of joint and soft tissue disease. Inherent
advantages of ultrasonography include accessibility,
quick scan time, low cost, multiplanar capability,
and the ability to perform real-time imaging with
contralateral comparison [32].

Thus, Scoles et al. [30] conclude in view of the
data they collected that the degree of maturity of
iliac crest in connection with secondary sexual
characteristics allows for sufficient conclusions
regarding the general progress of ossification in
relation to chronological age. Even when the hand
skeleton is fully developed, further reaching con-
clusions regarding chronological age can be drawn
by reference to the iliac crest apophysis [33,34].

Castriota-Scanderberg et al. [35] concluded that
ultrasonographic examination of the hip is a safe
and cost-effective method for assessment of skeletal
age, whereas Wagner et al. [36] suggested that
ultrasonography of the iliac bone apophysis and
distal radial epiphysis is a useful and highly ac-
teptable tool for bone age determination. So far,
collection and interpretation of radiological char-
acteristics of maturity of the pelvis have played a
decisive role mainly in the clinical area of appli-
cation.

The first basic knowledge of the development
of the iliac crest apophysis goes back to Risser
and Ferguson [37]. Their studies led to the devel-
opment of a classification of maturity based on X-
rays of the pelvis (so-called Risser stages), which
could be correlated with the residual potential for
overall growth of an individual. The stage of ossi-
fication of the iliac apophysis (Risser sign) is the
most commonly used method of determining skel-
etal maturation in patients with idiopathic scoliosis
[38-48]. According to Risser and other authors, the
ossification process starts at the time of the biggest
growth spurt in the antolateral area of the spina
iliaca anterior superior (ASIS) (Risser stage I) and
progresses posteromedially towards the spina iliaca
posterior superior (PSIS); apophyseal fusion with
more extensive parts of the iliac crest (Risser stage
V) is only observed on completion of skeletal
development [30,49]. Wagner et al. [36] were able
to combine requirements for radiation protection and
the advantages of a dynamic examination
procedure. In a subsequent study, the comparison
between sonographic and radiographic detection
of the Risser stage in 41 subjects showed a total
accuracy of the ultrasound examination of 90.2%
[50]. Thaler et al. [18] concluded that ultrasound
evaluation of the Risser Grade has proved to be
an accurate technique compared to radiographic
techniques. The technique is cheap, easy to use,
fast and easy accessibility.

The results of the present study showed that,
the mean values of the subjects’ chronological age
increase with progressive ossification stage. The
minimum age for ossification stage I was 13.6
years in boys; ossification stage I could not be
established in any of the female subjects of this
study group. The earliest observation of ossification
stage II was at a chronological age of 14.3 years
in males and 11.5 years in females. Ossification
stage III first occurred at the age of 16.4 years in
males and 15.4 years in females. The earliest age
of occurrence of ossification stage IV was at least
18.2 years in males and at least 17.3 years in
females. These results are in accordance with data
of Schmidt et al. [11] study who reported that
ossification stage I occurred in the male subjects
at a minimum age of 15.7 years. While, stage II
was diagnosed in boys at a minimum age of 14.1
years and in girls at a minimum age of 11.7 years.
The earliest observation of ossification stage III
was at a chronological age of 16.2 years in males
and 15.2 years in females, stage IV was at 18.0
years in male and at 17.1 years in female test
persons. These results are in harmony with previous
reports concerning skeletal maturation these reports
concluded that iliac crest usually appears at 16
years in males and 15 years in females, and fuses with the iliac bone at 19 years [51]. Racial, socioeconomic and environmental differences between Egyptians and other populations may cause differences in skeletal maturation. Therefore, it is expected that there should be some differences of skeletal maturation among different populations [52,53].

Conclusion:
The results of this study suggested that sonographic examination of the iliac crest apophysis can become established as a valid and efficient method for forensic age diagnostics in living individuals. Further researches for Egyptians are recommended using larger number of subjects from different regions.

References

