Comparison between Greulich-Pyle and Golden-Girdany methods for estimating skeletal age of children

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Aims and objectives

OBJECTIVE:

To compare the Greulich-Pyle (GP) and Golden-Girdany (GG) methods in the estimation of skeletal age (SA) in children referred to a tertiary care hospital.

INTRODUCTION

Skeletal maturity is one of the many objective methods of determination of age used worldwide. Radiographic investigations are the cornerstone to many such methods of age determination [1]. Accurate estimation of skeletal age (SA) is indispensable for social, legal and medicolegal purposes [2]. Furthermore, accurate SA estimation is also important in the realm of sports [3]. In the domain of diagnostic and therapeutic medicine, age determination has found uses in such fields as endocrinology [4], paediatrics [5] and orthodontics [6].

Many radiographic methods of SA determination have been described in the literature [7]. Greulich-Pyle (GP) method is one of the most popular radiologic methods used worldwide for the estimation of SA [8]. This method requires the comparison of radiographs of the hand and wrist of subjects against standardized images, published in the form of an atlas [9]. Another method of SA estimation utilized at our institute is the Girdany and Golden (GG) method [10]. In this method, a plain radiograph of various joints of the body is obtained and the SA is estimated based upon the appearance of ossification centres around these joints.

Although GP method alone is widely used for estimation of SA throughout the world, but in our country, both these methods are simultaneously being employed for the estimation of SA. This increases both the radiation exposure and financial burden on the patients. No study to date has been performed comparing the two methods head-to-head and the utility of using both these methods simultaneously. Therefore, in our study, we aimed to assess the efficiency of these two methods for the estimation of bone age. Moreover, we also planned to determine whether the use of a single method alone could replace the simultaneous use of both. In doing so, we might be able to justify or discourage the combined use of these methods, which can help in reducing the patients' financial burden and radiation exposure.

Methods and materials

An analytical study was carried out by reviewing plain X-ray films of wrist and elbow for the evaluation of trauma. This study was approved by the Ethical Review Committee of
our institution and the requirement of informed consent was waived. (2414-Rad-ERC-12) The data was retrieved using the Radiology Information System for all the children (up to 18 years of age) who underwent X-ray for the evaluation of trauma from 1\textsuperscript{st} July, 2010 to 31\textsuperscript{st} June, 2012. All children whose X-ray showed fracture, focal bone pathology or soft tissue abnormality were excluded from the analysis. Bone age was estimated for each individual using both GP and GG methods. All the X-rays were acquired using either Q-RAD (Shimadzu Medical Systems, Japan) or OTC 12S (DEL Medical Systems, USA).

**Greulich-Pyle method**

GP method is a method of bone age determination based on the comparison of radiographs obtained from individuals against a standardized set of images, originally published in the "Atlas of Skeletal Maturation of the Hand" in 1950 [9]. The comparison is based on finding the closest resembling image in the atlas through a detailed examination of the individual bones for appearance and fusion of the epiphyseal centres of ossification.

**Golden-Girdany method**

Golden and Girdany first published their standards in 1952 in the *American Journal of Roentgenology, Radium Therapy and Nuclear Medicine* [10]. This method also utilizes the time of appearance of various ossification centres for the purpose of bone age estimation and their comparison with the standardized images. However, in addition to the wrist joint, multiple other joints of the body may also used in this method, depending on age of the patient, including elbow, shoulder, spine, hip, knee and ankle.

**Image Interpretation**

Each radiograph was evaluated by two *independent* paediatric radiologists having at least 10 years of experience in reporting paediatric radiographs. The radiologists first estimated the SA using the GP method and the data were recorded on a structured proforma. One week later, the same radiologist employed GG method for the estimation of bone age. Both the reviewers were blinded to the actual chronologic age (CA) of the patients and to the findings reported by each other.

**Statistical Analysis**

Statistical Package for Social Sciences (SPSS) version 20 (IBM, Chicago, Illinois) was used for the purpose of data entry and analysis. Quantitative variables like age were expressed as mean ± standard deviation. Children of either sex were divided on the basis of CA in 4 groups based on previously established criteria by Lodler et al. [11] For males, Early Childhood (0-45 months); Middle Childhood (46-90 months); Late Childhood (91-159 months); Adolescence (160-216 months). For females, Early
Childhood (0-46 months); Middle Childhood (47-100 months); Late Childhood (101-159 months); Adolescence (160-216 months). For each age group, the mean CA among both sexes was compared using Student's t-test. Student's t-test was also utilized to determine if there was a significant difference between the CA and the mean ages estimated by the two methods. Pearson product-moment correlation coefficient was calculated to assess the strength of correlation between the SA estimated by each method and the actual CA. The level of agreement between the two methods was also determined using Bland Altman analysis. Finally, inter-observer agreement for both the methods was assessed using Intra-class correlation coefficient (ICC). A p-value of less than 0.05 was considered statistically significant.

**Results**

A total of 283 children of either sex up to the age of 18 years were included in the study. Among these children, 136 (48.1%) and 147(51.9%) were male and female respectively. The mean CA of our study subjects was 102.73 ± 4.9 months and 121.95 ± 5.2 months for boys and girls respectively. Moreover, no statistically significant difference was noted between the mean CA of both boys and girls amongst the four age groups (p=0.775, p=0.598, p=0.315 and p=0.488 respectively).

**Greulich-Pyle method**

The mean SA for boys and girls as estimated by GP method was 87.14 ± 5.3 months and 122.71 ± 5.8 months respectively. Using Student's t-test, no statistically significant difference was noted in the mean CA and the mean SA estimated by GP method for girls (p=0.695). However, for boys, a significant difference existed between the mean CA and the mean SA estimated by GP method (p<0.001). Student's t-test revealed that the mean SA estimated by GP method was not significantly different from the mean CA for girls in all the age groups. However, for boys in their middle and late childhood, there was a statistically significant difference between the mean CA and the mean SA estimated by GP method. No statistically significant difference existed between the mean CA and the mean SA for boys in their early childhood or adolescence.

**Golden-Girdany method**

The mean SA estimated by GG method was 80.6 ± 6.1 months for boys and 130.2 ± 7.1 months for girls. In contrast with GP method, the mean SA estimated by GG method was significantly different from the mean CA for both boys (p<0.001) and girls (p=0.011). Using Student's t-test, a statistically significant difference existed between GG method and CA for girls in their adolescent age group only. For boys, in contrast, a statistically
significant difference existed between the mean CA and the mean SA estimated by GG method for early, middle and late childhood groups.

**Comparison of GP and GG methods**

There was a statistically significant difference between the SA estimated by the two methods for girls in the middle childhood and adolescent groups. For boys in the early childhood group also, a statistically significant difference existed between the mean SA estimated by the two methods. Overall for girls and boys, there existed a significant difference between the two methods for SA estimation.

The overall comparison of between GP and GG methods with CA of children of all age groups of both sexes is depicted in table 1.

<table>
<thead>
<tr>
<th>AGE GROUP</th>
<th>MEAN CA</th>
<th>Mean SA (GP)</th>
<th>Mean SA (GG)</th>
<th>CA – GP</th>
<th>CA – GG</th>
<th>GP – GG</th>
</tr>
</thead>
<tbody>
<tr>
<td>MALE</td>
<td>102.73</td>
<td>87.14</td>
<td>80.60</td>
<td>-15.59 (.000)</td>
<td>-22.13 (.000)</td>
<td>-6.54 (.004)</td>
</tr>
<tr>
<td>0-45</td>
<td>31.35</td>
<td>27.71</td>
<td>11.87</td>
<td>3.64 (3.17)</td>
<td>19.48 (.000)</td>
<td>-15.84 (.000)</td>
</tr>
<tr>
<td>46-90</td>
<td>71.18</td>
<td>45.11</td>
<td>40.63</td>
<td>26.07 (0.000)</td>
<td>30.55 (0.000)</td>
<td>-4.47 (3.09)</td>
</tr>
<tr>
<td>91-159</td>
<td>129.84</td>
<td>110.74</td>
<td>106.26</td>
<td>19.10 (0.000)</td>
<td>23.58 (0.000)</td>
<td>-4.47 (3.15)</td>
</tr>
<tr>
<td>160-216</td>
<td>184.83</td>
<td>174.83</td>
<td>172.83</td>
<td>10 (0.061)</td>
<td>12 (0.255)</td>
<td>2.00 (7.35)</td>
</tr>
<tr>
<td>FEMALE</td>
<td>121.95</td>
<td>122.71</td>
<td>130.20</td>
<td>-0.76 (6.95)</td>
<td>8.25 (0.11)</td>
<td>-7.49 (0.01)</td>
</tr>
<tr>
<td>0-46</td>
<td>32.50</td>
<td>28.39</td>
<td>25.68</td>
<td>4.11 (1.89)</td>
<td>6.82 (1.89)</td>
<td>-2.71 (5.61)</td>
</tr>
<tr>
<td>47-100</td>
<td>69.31</td>
<td>68.85</td>
<td>59.31</td>
<td>0.46 (9.40)</td>
<td>10 (1.129)</td>
<td>9.54 (0.14)</td>
</tr>
<tr>
<td>101-159</td>
<td>124.30</td>
<td>124</td>
<td>129.86</td>
<td>-0.30 (9.47)</td>
<td>-5.57 (3.91)</td>
<td>-5.86 (1.28)</td>
</tr>
<tr>
<td>160-216</td>
<td>189.57</td>
<td>194.04</td>
<td>215.59</td>
<td>-4.47 (1.01)</td>
<td>-26.02 (0.000)</td>
<td>-21.55 (0.000)</td>
</tr>
</tbody>
</table>

**Table 1**: Overall Comparison of CA and Mean SA estimated by both GP and GG methods in both boys and girls. (All ages in months)
CORRELATION BETWEEN CA AND SA:

The correlation between the mean CA and the mean SA for both the methods in either sex is shown in Figure 1.

Fig. 1: Correlation between CA and SA estimated by both the methods in boys and girls.

References: Aga Khan University, Aga Khan University Hospital - Karachi/PK
A stronger correlation was found between the mean CA and the mean SA determined by GP as compared to the GG method for both male and female children. In girls, the Pearson's moment product correlation coefficient was 0.943 ($p<0.001$) for GP method and 0.909 ($p<0.0001$) for GG method. The Pearson's moment product correlation coefficient was 0.943 ($p<0.001$) for GP method and 0.909 ($p<0.0001$) for GG method.
coefficients in boys for GP and GG methods were 0.915 ($p<0.001$) and 0.865 ($p<0.001$), respectively.

**LEVEL OF AGREEMENT BETWEEN THE TWO METHODS:**

Bland Altman Plot was utilized to assess the agreement between the two methods as shown in figure 2.

![Bland Altman Plot](image)

**Fig. 2:** Bland Altman plot for GP and GG method showing clinically significant discrepancy between the two methods in both boys and girls.

**References:** Aga Khan University, Aga Khan University Hospital - Karachi/PK

The analysis illustrate that within 95% confidence limits, the agreement between GP and GG methods fell between -57.8 to +44.7 months for boys and -46.5 to +61.5 months for girls. This implies that there exists a clinically significant discrepancy of up to 58 months for boys and 62 months for girls in determining SA between these two methods.

**INTEROBSERVER AGREEMENT:**

Overall, there was excellent agreement between the two radiologists in estimating SA using both the methods. However, it was better for GP (ICC = .998) as compared to GG method (ICC = .974), suggesting lesser variations for the GP method between different readers.

**LIMITATIONS:**
However, before coming to any definite conclusions, limitations of our study should be borne in mind. First and foremost, our study was based on a sample of children who had presented for the evaluation of trauma at a tertiary care hospital. This hospital-based sample of children may differ significantly from the general population and thus may not be truly representative of healthy children. Furthermore, convenience sampling was used in this study, which again may pose problems when generalizing the results of this study to the general population. Ethnicity may be a significant confounder in our analysis, which was not controlled for and thus may have influenced the results of this study.

Despite the limitations of this study, the strengths of this study also merit attention. First and foremost, this study is the first study to analyze the use of GG method for the determination of SA in children. Secondly, this study is the first to provide a head-to-head comparison between GP and GG methods, which has not been reported in the published literature before. Last but not the least, as both the GP and GG methods are being utilized concurrently in our country, the results of our study are the first to suggest that the use of GP method alone may be equally effective. This has important implications for clinical practice in terms of cost, radiation exposure and feasibility. Finally, neither GP nor GG methods were reliable for the estimation of SA in Pakistani boys. This finding can have major implications for medical and legal domains. Given the fact that the findings of our study are in line with previous reports from the country[12, 13] it is imperative that indigenous standards of SA be developed by studying a larger representative sample of healthy children from our own population.

**Conclusion**

Our study showed that there is no additional benefit of using GP and GG method simultaneously over using GP method alone. Moreover, although GP was reliable in estimating SA in girls, it too was unable to accurately assess the SA in boys. Therefore, best would be to develop indigenous standards of bone age estimation based on a representative sample of healthy native children.

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**Personal information**
Dr. Muhammad Awais is working as an year II Resident in the Department of Radiology, Aga Khan University Hospital Karachi, Pakistan. Dr. Awais did his MBBS from Khyber Medical College, Peshawar and did his internships in Medicine at Khyber Teaching Hospital and in Radiology at Lady Reading Hospital, Peshawar.

References


