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Research Article

Ossification of Distal end of Radius & Base of Fist Metacarpal in Forensic Age Estimation in the Kerala Population

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Abstract: 88 Wrist X-Rays of children from Kerala, Mahe and Lakshadweep aged 5.5 years of less were analyzed in this study to glean data of ossification of distal end of radius and the base of first metacarpal. The data could be useful in forensic age determination in the practical setting.
Keywords: Age determination, Distal end of Radius, Forensic Age Estimation, First Metacarpal (Base), Kerala Data

INTRODUCTION

In Kerala the data widely used for forensic age determination from ossification changes [1] is not based on any study published in peer reviewed scientific journals. One study was conducted on the skeletal changes in Calicut (Kozhikkode) in the year 1977 [2], but it has never been published. It has been menntioned in an undergraduate textbook[3], but has not been adopted as a part of the 'Kerala Data'.

The data collated in the Calicut study itself is incomplete since it does not include many important ossification events like appearance of the base of first metacarpal and the distal ends of radius and ulna. This indicates that there is a dearth of published scientific studies which substatiate the values of ossification (age cutoffs) followed in the state. The present study attempts to partially fill the gap by collating the time of appearance of the ossification center for the distal end of Radius, and the base of first metacarpal.

The legal standards of "preponderance of evidence" and "beyond reasonable doubt" require proof approaching 100% probability [4]. So the tests used in forensic age determination should predict the age with a high degree of accuracy. There is a need to assess the sensitivity and specificity of the age cut-offs.

MATERIALS AND METHODS

The present study is modeled as evaluation of diagnostic tests. It also attempts to formulate diagnostic tests where the sensitivity and specificity of each possible prediction is known. 88 wrist X-Rays of children aged less than five and half years taken in the year 2010 and first six months of 2011 were (18 month period) collected from the digital archives of Amrita Institute of Medical Sciences were used for the study. Since this is a retrospective study, it was not possible to evaluate the socioeconomic status of the children; but it was possible to ascertain the residential addresses, complete clinical histories, investigation results, growth charts etc.

The age of the child as recorded in the documents was utilized for the study. In those cases where the child was delivered in the hospital, the age was entered into the system by the hospital staff and in other cases; it was stated by the parents. For tabulation purposes, the age at the time of taking the X-Rays was calculated by counting the number of days between the date of birth and the date of taking X-Ray and dividing it by 365. However, for the purpose of compiling age of ossification, age is counted in years and months.

The present study included X-Rays of both hands. Differences in the ossification of centers between the right and left sides have been noted in literature [5], but the present study does not analyze this difference. There were some cases were X-Rayed more than once. In such cases, the two X-Rays were considered as two cases if they were taken more than 6 months apart. In the present study, there was one such case in which two different X-Rays of the same child was taken 1 year and 16 days apart.

Anyone diagnosed with nutritional deficiency; genetic abnormalities; endocrine diseases; global developmental delay and those cases where stature fell below the 3rd percentile or went above 97th percentile were excluded from the study. The study was confined to residents of Kerala. A case each from Mahe and Lakshadweep were included; but one case each from Tamil Nadu, Maharashtra and Maldives were excluded.

235 X-Rays were collected in all. Out of this, 145 X-Rays met the exclusion criteria and were discarded. The

remaining X-Rays were read by two forensic medicine experts who did not have access to the chronological age and determined independently whether a center had appeared or not. Two more cases because the positioning did not permit observation of all the centers covered in this study. After the multi tired exclusion process, only 88 X-Rays remained.

Since the 'Kerala Data' does not give different values for males and females for the ossification centers studied, the specificity of 'Kerala Data' was determined for the whole population in the present study.

The results were subjected to ROC Chart analysis. The co-ordinates of the charts with the specificity and sensitivity of each age cutoff value was prepared for analysis of the accuracy of prediction for each available cutoff points. Age range for the appearance of both centers under the study was determined so that diagnosis of age could be made with maximum accuracy possible. At the age cutoff where there is maximum sensitivity was taken as the lower limit of the age range and the cutoff with maximum specificity was taken as the upper limit.

RESULTS

Even though 10 out of 14 districts in Kerala were represented in the study, a disproportionately large number of cases were from the Ernakulum and surrounding districts (Figure 1). 70.5% of the cases were from Ernakulam, Thrissur and Kottyam districts. Four districts (Thiruvananthapuram, Malappuram, Wayanad and Kannur) were not represented in the study.

The sex distribution was even with 43 girls and 45 boys in the study group (Table 1).

Fig. 1: The distribution of cases. Note that there is a high concentration of cases from Ernakulum and nearby districts

Table 1: Age and sex wise breakdown

Age Groups	Male	Female	Total
<0.5	5	4	9
0.6-1.0	9	9	18
1.1-1.5	5	10	15
1.6-2.0	8	9	17
2.1-2.5	5	2	7
2.6-3.0	4	4	8
3.1-3.5	2	3	5
3.6-4.0	1	1	2
4.1-4.5	4	0	4
4.6-5.0	1	0	1
5.0-5.5	1	1	2
	45	43	88

Distal End of Radius

As per the 'Kerala Data'[1], the ossification center for the distal end of radius appears at the age of 2. As per the Bengal study (Galstaun) this event happened at 1 year [6]. The study conducted at Delhi [3] on a mixed population gave the value as 1.7 +/- 0.9years for females and 3.5 +/- 1.5 years for males (Table 2). In the present study, the earliest age when the distal end was seen (Figure 2) in X-Rays was at 9 months and 14 days (0.8y). The oldest individual who did not show evidence of ossification of the distal end of radius was aged 2 years 1 month and 22 days (2.1y) (Figure 2).

Table 2: Comparison of Kerala Data with other studies

	'Kerala Data' [1]	**Galstaun [6] (Bengalis)**		**Lall & Nat (Males of U.P.) M. Hassan & D. Naraian [6]**	**Bajaj et al 1967 Delhi mixed population[3]**	
		♀	♂		♀	♂
Distal end of Radius	**2y**	1 y	1 y	NA	1.7 (+/- 0.9)	3.5 (+/- 1.5)
Base of 1st Metacarpal	**4y**	3 y	4 y	NA	2.1 (+/- 1.0)	4.2 (+/- 1.5)

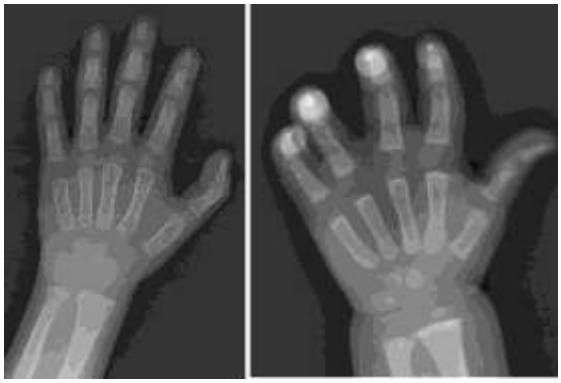

Figure 2: Appearance of Distal End of Radius- The left image shows wrist X-Ray of the oldest child in the sample where distal end of radius had not ossified (age: 2 years 1 month and 22 days). The image to the right is that of the youngest child whose X-Ray showed ossification of the center (age: 9 months and 14 days)

An ROC Curve (Figure 3) was plotted using the co-ordinates (Table 3). The area under the curve was 0.934. The test result variable (Age) was shown to have at least one tie between the positive actual state group (those with radiologically demonstrable ossification of distal end of raidus) and the negative actual state group.

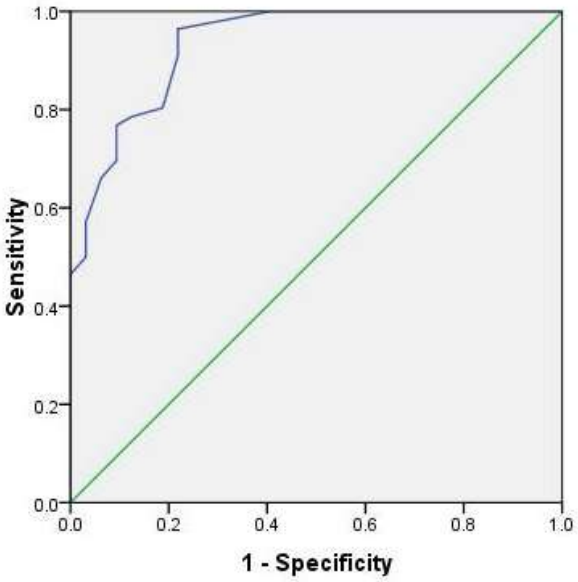

Fig. 3: ROC Curve for appearance of distal end of radius. Diagonal segments are produced by ties. The area under the curve is 0.934. The test result variable (Age) has at least one tie between the positive actual state group (distal end of radius has appeared) and the negative actual state group

Table 3: Co-ordinates of the ROC Curve for appearance of the distal end of radius and the base of first metacarpal(the cutoffs which limit the age range is highlighted).

Positive if greater than or equal to Age	Distal end of Radius		Base of First Metacarpal	
	Sensitivity	Specificity	Sensitivity	Specificity
.650	1.000	0.406	1.000	0.236
.750	***1.000***	0.594	1.000	0.345
.850	.982	0.688	1.000	0.418
1.000	.964	0.781	1.000	0.491
1.150	.911	0.781	***1.000***	0.527
1.250	.804	0.812	.938	0.618
1.350	.786	0.875	.938	0.673
1.500	.768	0.906	.906	0.691
1.650	.696	0.906	.844	0.727
1.750	.661	0.938	.844	0.782
1.850	.571	0.969	.781	0.855
1.950	.536	0.969	.719	0.855
2.050	.500	0.969	.656	0.855
2.150	.464	***1.000***	.656	0.909
2.300	.411	1.000	.594	0.927
2.550	.393	1.000	.594	0.945
2.750	.375	1.000	.562	0.945
2.850	.339	1.000	.531	0.964
2.950	.321	1.000	.500	0.964
3.050	.250	1.000	.375	0.964
3.200	.214	1.000	.344	0.982
3.400	.179	1.000	.312	***1.000***
3.550	.161	1.000	.281	1.000

The data suggests that if 0.75 years (9 months) is taken as the lower limit of the age range and 2.150 years (≅ 2 years and 2 months) is taken as the upper limit, we will get the maximum sensitivity and specificity. The age range of 9 – 26 months will give most accurate results when used for forensic age estimation. The sensitivity and specificity of other age cut offs can be seen in Table 3.

Base of 1st Metacarpal

As per the 'Kerala Data'[1], the base of first metacarpal appears at the age of 4 years. As per the Bengal study (Galstaun) this event happens at 3 years in females and 4 years in males [6]. The study conducted in Delhi [3] gave the value as 2.1+/- 1.0 years in the case of females and 4.2+/-1.5 years in the case of males (Table 2). In the present study, the oldest individual X-Ray where the center had yet to appear was aged 3 years 3 months and 27 days (Figure 4). The youngest individual with the center present was aged 1 year 2 months and 12 days (Figure 4).

An ROC Curve (Figure 5) was plotted using the co-ordinates (Table 3). The area under the curve was 0.901. The test result variable (Age) was shown to have at least one tie between the positive actual state group (those with radiologically demonstrable ossification of distal end of raidus) and the negative actual state group.

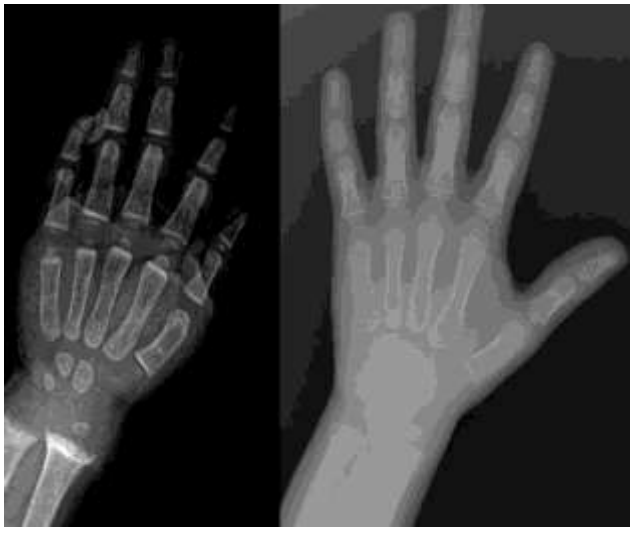

Fig. 4: Base of 1st metacarpal- The image on the left shows the X-Ray of the youngest individual who showed base of first metacarpal (age: 1 year 2 months and 12 days). The oldest individual X-Ray where the center had yet to appear was aged 3 years 3 months and 27 days (the image on the right).

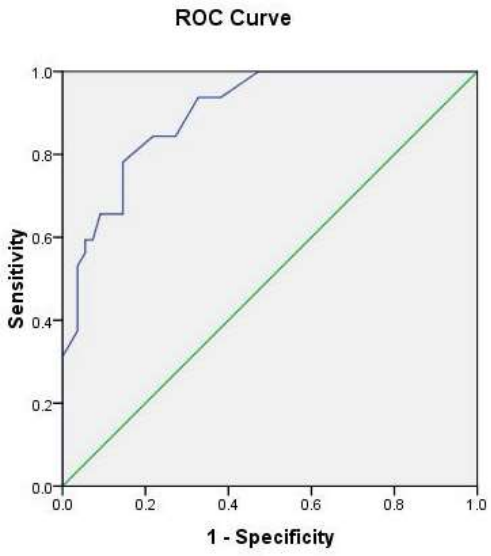

Fig. 5: ROC Curve for appearance of base of first metacarpal. Diagonal segments are produced by ties. The area under the curve is 0.901. The test result variable (Age) has at least one tie between the positive actual state group (base of first metacarpal has appeared) and the negative actual state group.

The data suggests that if 1.150 years (≅ 1 year and 1 month) is taken as the lower limit of the age range and 3.400 years (≅ 3 years and 5 months) is taken as the upper limit, we will get the maximum sensitivity and specificity. The age range of 13 – 41 months will give most accurate results when used for forensic age estimation. The sensitivity and specificity of other age cut offs can be seen in Table 3.

DISCUSSION AND CONCLUSION

Like the other ossification centers, the ossification of the bony centers of hands and wrist is also subject to much variation. The order of appearance of centers itself show variability in the case of wrist X-Rays [7]. It is important that this variability is taken into consideration when tests are devised for forensic age determination.

The present study showed a age range for ossification of both the centers (Table 5). Distal end of Radius was seen to appear at age above 0.75 and below 2.150 (between 9months and 2 years 2 months). The appearance of distal end of radius in the present study overlapped both the 'Kerala Data' as well as the data obtained from Bengal (Table 2). The base of first metacarpal was seen to appear between 1.15 and 3.4 years (1year 1 month to 3year 5 months). The ossification of this center occurred over an age range which encompassed the 'Kerala Data' as well as the Bengal study (Galstaun) (Table 2) but was considerably wider than both.

Table 5: The age ranges when ossification of the centers occur. The lower limit gives maximum sensitivity and the upper limit gives maximum specificity

Center	Age in adjusted years	Age optimized for forensic age determination
Distal end of Radius	0.750 – 2.150	9m – 2y 2m
Base of First Metacarpal	1.150 – 3.400	1y 1m – 3y 5m

The authors feel that a series of studies to collect and standardize data from all parts of the state and analysis of parameters like differences due to socio-economic factors and sex is needed. Atlases like GOK, the Greulich-Pyle (GP), and the Tanner-Whitehouse (TW3) which are widely used for forensic age estimation [8] can also be adopted for our population instead of the method in use now. Forensic age determination is typically based on multiple factors like physical development, dental data and ossification data. If we understand the accuracy of each of these parameters better, and use check lists on sensitivity and specificity; it would perhaps be easier to combine the results better and to give precise opinion on age.

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