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Ulnar variance in children – standard measurements for evaluation of ulnar shortening in juvenile rheumatoid arthritis, hereditary multiple exostosis and other bone or joint disorders in childhood

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Abstract. Measurements for radioulnar variance in adults cannot be used in children because the epiphyses are not fully ossified. We describe a method of determining ulnar variance in children by using the distance from the distal metaphysis of the radius to the distal metaphysis of the ulna. Standards for this measurement are presented for ages 1.5 to 15.5 years in boys and girls. These measurements change little with age and may be helpful in establishing shortening of the ulna which may be seen in juvenile rheumatoid arthritis, hereditary multiple exostosis, or other bone and joint diseases with childhood onset.

Key words: Ulnar variance – Distal radioulnar discrepancy – Ulnar shortening – Carpal subluxation – Juvenile rheumatoid arthritis – Hereditary multiple exostosis

The relative position of the distal ulna and radius has been determined in the adult [2, 4, 5, 6] by various methods of measurement. These measurements were used primarily in the evaluation of Kienböck disease in which a relatively short ulna was observed. Hulten used the terms negative ulnar variance when the distal ulna is shorter than the radius, neutral variance when both bones end at the same level, and positive ulnar variance when the distal ulna exceeds the radius [3].

Kienböck disease is rarely seen in children and the measurements made in this disease all refer to adult patients with fully developed ossification. There are on the other hand a number of pediatric conditions with a short ulna in which it would be useful to have some standards. Adult standards cannot be used because of the variable ossification of the epiphyses. Impaired growth of the distal ulna may occur in children with juvenile rheumatoid arthritis or other forms of arthritis with childhood onset. In some of these patients the short ulna favors ulnar subluxation of the carpals [8]. A short ulna may also be seen in hereditary multiple exostoses [7]. In order to evaluate possible shortening of the ulna in these patients, we determined standards for distal radioulnar discrepancy by a simple measurement which can be applied to children of all ages.

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Material and methods

A sample of 535 hand X-rays from healthy children was used to establish standards. This collection of radiographs was part of the Ten State Nutritional Survey that consisted of 259 girls and 276 boys. They were divided into age groups at one-year intervals. Age ranged from 1.5 to 15.5 years in boys and 1.5 to 14.5 years in girls, with approximately 20 boys and 20 girls in each age group. The hand was in neutral position on these radiographs.

For measuring the ulnar variance, a midline was drawn parallel to the long axis of the ulna. Two perpendicular lines were then drawn: one touching the most proximal, the other the most distal point of the distal metaphysis of the ulna. Two similar lines marked the same points at the radial metaphysis (Fig. 1). With these four lines, four possible measurements were available:

A. Distance from the most proximal point of the ulnar metaphysis to the most proximal point of the radial metaphysis

B. Distance from the most distal point of the ulnar metaphysis to the most distal point of the radial metaphysis

C. Distance from the most proximal point of the ulnar metaphysis to the most distal point of the radial metaphysis

D. Distance from the most distal point of the ulnar metaphysis to the most proximal point of the radial metaphysis

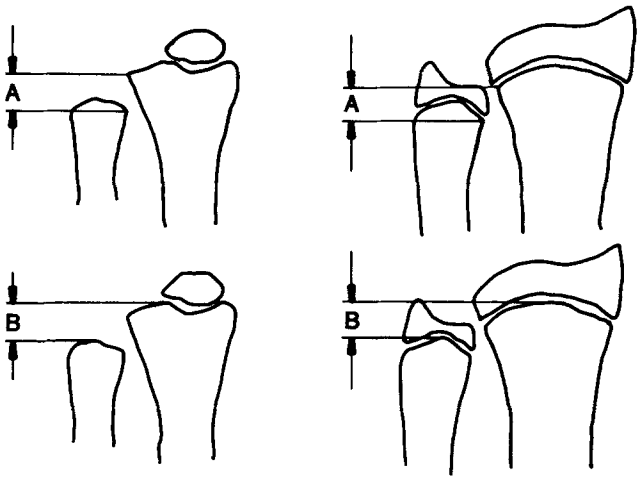

Fig. 1 A, B. Method used to measure ulnar variance. **A** Distance from the most proximal point of the ulnar metaphysis to the most proximal point of the radial metaphysis. **B** Distance from the most distal point of the ulnar metaphysis to the most distal point of the radial metaphysis.

Results

The approach taken was to model a simple linear regression of the measurements on age and sex. The sex variable was not significant in any of the four scales and generally did not contribute to the model ($p > 0.2$ in each case). However, it is seen that heteroskedasticity exists in the model for each measurement. An analysis of the residuals followed and Glesjer tests confirmed that there was a strong indication that either the variances were proportional to the square root of the age, or that the variances were proportional to the age ($p < 0.01$ for both cases for each scale). A transformed model based on the first case was determined to be the more desirable model. From this, a 95% confidence interval of an individual observation for each age scale was determined taking into account the heteroskedasticity. The results are shown in Table 1. A spread is given indicating the maximum confidence bound distances for ages 2 to 16 years.

Table 1. Means and 95% confidence intervals (C.I.) for one observation

Age (years)	Measurement A			Measurement B		
	Mean (mm)	95% C.I. (mm)		Mean (mm)	95% C.I. (mm)	
		From	To		From	To
2	2.1	0.3	3.8	2.3	0.7	4.1
3	2.1	−0	4.2	2.4	0.3	4.5
4	2.1	−0.3	4.6	2.4	0	4.8
5	2.1	−0.6	4.9	2.4	−0.2	5.2
6	2.1	−0.9	5.1	2.5	−0.4	5.5
7	2.2	−1.1	5.4	2.5	−0.6	5.7
8	2.2	−1.3	5.6	2.5	−0.8	6.0
9	2.2	−1.4	5.9	2.6	−1.0	6.2
10	2.2	−1.6	6.1	2.6	−1.1	6.5
11	2.2	−1.8	6.3	2.6	−1.3	6.7
12	2.2	−2.0	6.5	2.7	−1.4	6.9
13	2.2	−2.2	6.7	2.7	−1.5	7.1
14	2.3	−2.4	7.0	2.7	−1.7	7.3
15	2.3	−2.4	7.0	2.8	−1.8	7.5
	regression line $A = 2.04 + (0.15 \times \text{age})$			regression line $B = 2.25 + (0.034 \times \text{age})$		
	standard error of slope = 0.017			standard error of slope = 0.017		

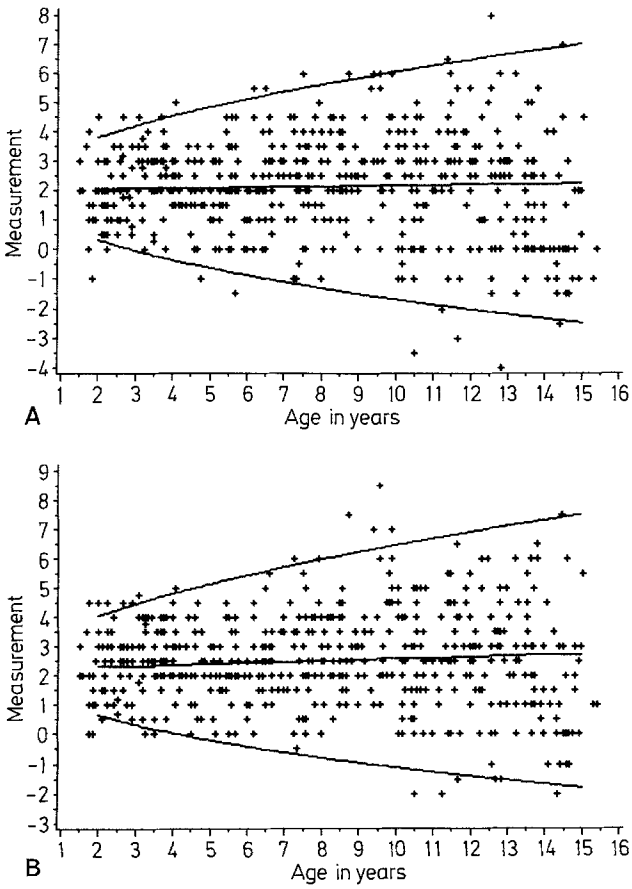

Fig. 2 A, B. Distribution of ulnar variance in a healthy population of 535 children. **A** for measurement A, **B** for measurement B

The four scales exhibited similar error estimates, ranging from 0.357 for scale B to 0.391 for scale D, translating to a difference of 0.2 – spread in the confidence interval at age 16 years. Specification of the first and second moments indicated that scale A was the best specified, i.e., after adjusting for age and the relationship between age and the variance, the residuals exhibited the least discernible pattern. This can be partially seen in the plots. In the case of scales C, D, and B the

outliers seem asymmetric in either the numbers or distances of these observations from the expected value. Thus while model B has the lowest error, model A may be most desirable in determining whether the measurement of the hand is within normal limits.

Figure 2 illustrates the distribution of all the children used in the standards. It can be noted that the measurements A and B change very little with age while the range of normal increases significantly with age.

Discussion

Several methods to determine ulnar variance have been described in adults [2, 4, 5, 6]. However, they cannot be applied to children in whom the epiphyses are not fully ossified. We therefore suggest a measurement for children that refers to the distal metaphyses of the radius and ulna as measuring points. This method proved helpful in evaluating children with open growth plates of the radius and ulna. We determined standards of radioulnar discrepancy for children up to 15 years of age.

Several bone and joint disorders in childhood result in relative shortening of the distal ulna. There may be a major susceptibility to growth disturbance in this bone. We find ulnar shortening in many patients with juvenile rheumatoid arthritis. By using our measurements and standards for ulnar variance in children we can detect such a change in patients with impaired ulnar growth and distinguish it from a negative ulnar variance which may still be within the normal range. The measurements are also useful to determine the increase of ulnar shortening during follow-up in children with progressive disease and may help identify patients with a higher risk for ulnar subluxation of the carpals (Fig. 3A and B).

Ulnar shortening is also seen in other forms of juvenile arthritis such as juvenile spondyloarthritis, arthritis in connective tissue disease, or infantile sarcoidosis (Fig. 4). The most severe growth disturbances of the ulna can be found in multiple exostoses (Fig. 5) and in carpal tarsal osteolysis. In all these disorders our standard measurements for radioulnar discrepancy may help to determine the degree of ulnar shortening. These measure-

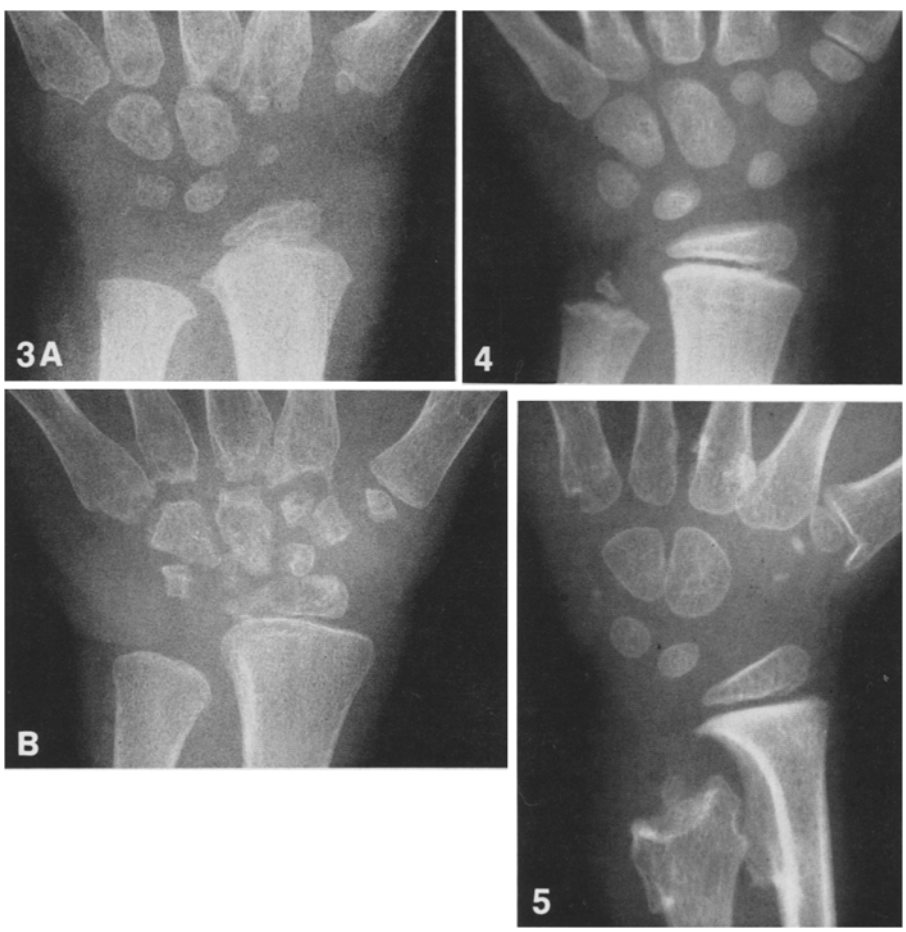

Fig. 3. Wrist X-ray of a child with juvenile rheumatoid arthritis at age 2.5 years (**A**) and 3.5 years (**B**). Increase of ulnar shortening with progressive disease. Measurements A and B were 3.5 mm and 4.5 mm at age 2.5 years which is at about the 95th percentile. They increased to 6 mm and 5 mm at age 3.5 which is well above the 95th percentile. Note the tendency towards ulnar subluxation of the carpals

Fig. 4. Marked ulnar shortening in a 6-year-old girl with polyarthritis from infantile sarcoidosis. Measurement A was 17.5 mm and B 7 mm, both of them well above the 95th percentile

Fig. 5. Severe growth disturbance of the ulna in a 5-year-old boy with hereditary multiple exostosis. Measurement A was 10 mm and B 8 mm, both markedly outside the 95th percentile

ments may also be applied to patients with impaired growth of the radius which has been described in gymnasts [1].

Our standards for ulnar variance in children show only slight variation with age; therefore, in patients with accelerated bone age due to hyperemia of arthritis or retarded bone age of various causes the results do not differ significantly whether bone age or chronologic age is used for measurement.

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