VALIDATION AND REPRODUCIBILITY OF MAGNETIC RESONANCE IMAGING OF SKELETAL AGE

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Introduction

Skeletal age is frequently used to evaluate the growth of children and is determined by assessing skeletal maturity in the analysis of the ossification centers and epiphyseal plate fusion of the left hand and wrist. Tanner and Whitehouse[1] (TW2) systems and Greulich and Pyle [2](GP) are the most popular methods based on evaluating an X-ray film. In the TW2 system, the user assigns a maturity stage to each bone (A to I), while in the GP system the user matches the hand to one of the reference images in the GP atlas. However, standard radiographs have radiation risks which cannot be justified as a screening tool for children. The use of MRI to estimate skeletal age is a novel idea. MRI also has superior soft tissue contrast and multiplanar cross sectional imaging capability. Therefore, the purpose of this study was to assess skeletal age using MRI and evaluate its validity.

Materials and Methods

A total of 93 Japanese healthy children (50 boys and 43 girls) aged from 4.1 to 15.1 (mean 9.7), were recruited from the local community. Written informed consent was received both by themselves and by one of their parents before the MR examination. All MR measurements were performed under the approval of the ethical committee of our institute. MR images of the children's left hand were acquired using a compact permanent-magnet MRI system developed by University of Tsukuba and MR Technology Inc. (Tsukuba, Japan) [3]. The specification of the magnet is as follows: field strength = 0.3 T; horizontal gap = 142 mm; homogeneity = 50 ppm over the $22 \times 22 \times 8$ cm^3 diameter ellipsoidal volume; weight = 700 kg. A 3D coherent gradient-echo sequence (dwell time = 20 µs; TR/TE = 40/11 ms; FA = 60°; matrix size = $512 \times 128 \times 32$; FOV = $200 \times 100 \times 50$ mm^3, total acquisition time = 2 min 44 s) was used. The data sets were zero-filled in the coronal phase-encoding direction to obtain isotropic voxel (1.56 mm cube). Skeletal age was rated independently by two readers (A and B) who were blinded to the children's age, according to the TW-Japan RUS system (RUS stands for radius, ulna and the 11 short bones in rays 1, 3 and 5) (Assessment of skeletal age for Japanese children, Medical View, Tokyo, Japan). Reader A rated the images twice after a two-week interval (A1 and A2). In the statistical analysis, the correlation between chronological age and MRI skeletal age was determined by means of a simple linear regression analysis. Pearson's correlation coefficient (r) was used to measure inter-reader (A1 vs B, A2 vs B) and intra-reader (A1 vs A2) reproducibility.

Results

Eighty-three out of 93 cases were rated. Four cases (age range = 5.3-9.1 years; mean = 6.9 years) were excluded because of severe motion artifact and 6 cases (age range = 13.2-15.8 years; mean = 14.4 years) were not able to be evaluated because the distal phalangeal joint was out of FOV or demonstrated significant signal loss. The chronological age and MRI skeletal demonstrated a strong positive linear correlation by reader A1, A2, and B with 0.921, 0.909 and 0.866, respectively (Figure2). In the intra-reader reproducibility for the MRI assessment, Pearson's r was 0.958 (A1 vs A2). In the inter-reader reproducibility, Pearson's r was 0.922 (A1 vs B), and 0.926 (A2 vs B), respectively. Two or more stage difference in each bone between readers A1, A2 and B was defined as disagreement of stage and shown in Fig. 3. Disagreement of stage was most frequently seen in the ulna and fifth metacarpal bone. However, there was no significant correlation between the chronological age and the number of disagreement of stage.

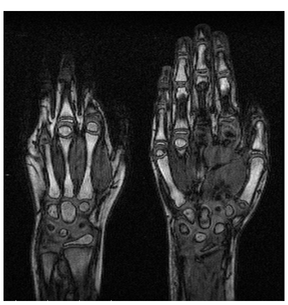

Fig 1. 3D MRI of the hand and wrist

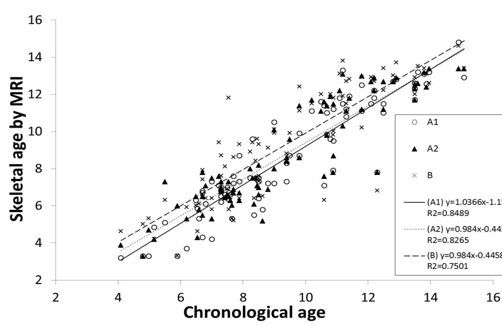

Fig 2. Correlation between chronological age and MRI skeletal age

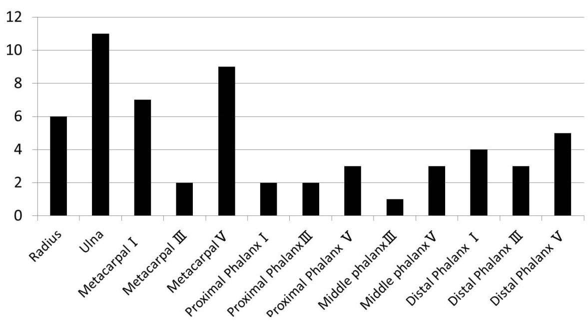

Fig 3. Number of stage disagreement*
*Two or more stage difference in each bone

Discussion

The International Atomic Energy Agency (IAEA) has concerns about x-ray examination for healthy children[4] and has raised the necessity for an alternative method for determining age and maturity. MRI is non-invasive and could be an alternative method of the skeletal age examination. Dvorak et al reported the assessment of skeletal age using MRI in adolescent male football players[4]. However, there have been no reports for skeletal age MR examinations in wide ranges of age using TW2 or GP, so far. In the present study, there was a strong positive correlation between chronological age and skeletal age by MRI. The intra-reader and inter-reader reproducibility were high. There are several limitations in the present study. Some young children had difficulty remaining still for the entire examination, although the MR scan time was approximately 2.5 minutes. The hand of some adolescents was too large to include the distal phalanx within FOV. We may need MRI of the wrist and distal hand separately for these adolescents. Despite these limitations, we believe MRI could be a non-invasive and non-radiation method of assessment of skeletal age.

References

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