Skeletal age assessment using a new dedicated hand MRI system for young children

Yasuhiko Terada[1], Saki Kono[1], Tomomi Uchiumi[1], Kazunori Ishizawa[1], Shinya Inamura[1], Katsumi Kose[1], Ryo Miyagi[2,3], Eiko Yamabe[2], Yasunari Fujinaga[2], and Hiroshi Yoshioka[2]

[1]*Institute of Applied Physics, University of Tsukuba, Tsukuba, Ibaraki, Japan,* [2]*Department of Radiological Sciences, University of California Irvine, Orange, CA, United States,* [3]*National Health Insurance Nishi-iya Clinic, Tokushima University, Miyoshi-shi, Tokushima, Japan*

INTRODUCTION

In a previous study, we showed the validity of the MR skeletal age assessment of children using an open, compact MRI system [1,2]. However, the magnetic circuit used previously was designed to image an adult hand, and was large for young children. Therefore, children under 4 were not examined, and in some examinations, the subject's arm was short and the unnatural posture of the body introduced a sever motion artifact. In this study, we use a smaller permanent magnet to develop a new, dedicated MRI system for the skeletal age assessment of children, and prove the validity of the examination using the new system.

MATERIALS AND METHODS

A total of 88 healthy children aged from 3.4 to 15.7 (mean 8.8, 65 boys and 23 girls), were recruited from the local community. Written informed consent was obtained from both the child and one of the parents. All MRI measurements were performed under the approval of the ethical committee of our institute. The compact MRI system consisted of a C-shaped Nd-Fe-B permanent magnet (Fig. 1(a)), a solenoid-type RF probe, a gradient coil set, and an MRI console. The specifications of the magnet were field strength = 0.3 T, gap width = 12 cm, size = 57 × 40 × 41 cm^3, weight = 450 kg, and homogeneity = 16 ppm over 16 × 12 × 5 cm^3 diameter ellipsoidal volume. A 3D coherent gradient-echo sequence (dwell time = 20 μs; TR/TE = 40/11 ms; FA = 60°; matrix size = 512 × 128 × 32; FOV = 20 × 10 × 5 cm^3, total acquisition time = 2 min 44 s) was used twice for each subject to image the proximal and distal parts separately. Skeletal age was rated independently by three raters (orthopedic specialists A and B, and a radiologist C) who were blinded to the children's age, according to the Tanner–Whitehouse 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). Rater A rated twice after a week interval (A1 and A2). The average values of Cohen's weighted κ [3] between raters were calculated to evaluate agreement of rating between multiple raters. The average values of κ and the ratio of cases excluded from rating were compared with those obtained in the previous study [1,2] (in which a 93 healthy children aged from 4.1 to 15.1 (mean 9.7, 50 boys and 43 girls) were examined using the previous system and rated by raters A and B).

RESULTS

As shown in Fig. 1(b), in most cases, the quality of MR images was high enough to allow the MR skeletal rating. In average, 5.7 cases (6.4 %) out of 88 cases were excluded from the rating. Sever motion artifact was observed in 4.3 cases (4.9 %), and some bones were out of FOV in 3.3 cases (3.8 %). The correlation between the skeletal and chronological ages was high, and the Pearson's r was 0.899, 0.898, and 0.899 for A1, B, and C, respectively (Fig. 1(c)). The intra-rater reproducibility was high (r = 0.918 (A1 vs A2)). The κ values were over 0.8 for most bones (Fig. 1(d)), revealing the substantial agreement of rating between three raters.

DISCUSSION

The advantage of the new system is that a small magnet is used (33 % reduction in size). The distance from the magnet edge to the FOV center is 20 cm, which was short enough for the youngest 3.4-year-old volunteer (Fig. 1(a)) for whom no motion artifact was observed. The installation space for the magnet was also reduced. These improvements enhanced the openness of the system and provided stress-free examinations. Meanwhile, the B_0 homogeneous area was small, and the proximal and distal parts were imaged separately. This enabled the reliable assessment of development stages for all bones. Indeed, for most bones, the κ values were higher than previously (Fig. 1(d)), and the total ratio of excluded cases from rating was also lower (Fig. 1(e)). Meanwhile, the doubled measurement time infrequently leaded to the appearance of motion artifact, especially in the second (distal part) image. This could be overcome by the shortening of the scan time with the aid of, for example, partial Fourier acquisition and the more stable fixation of the distal part.

In conclusion, we developed the new, dedicated MRI system which provides stress-free and less fearful examinations for young children, and showed the validity of MR skeletal examination using the new system.

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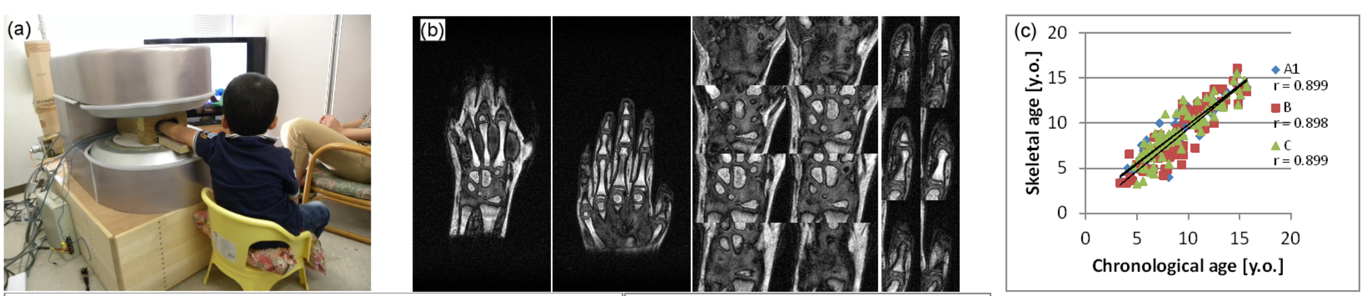

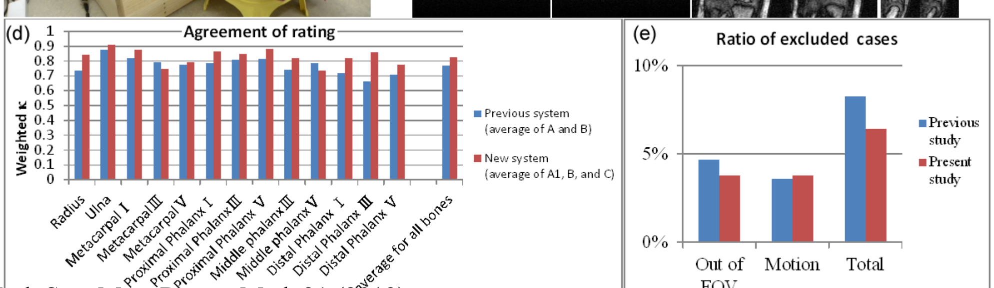

Figure 1 (a) Snapshot of MR examination for a boy aged 3.4. (b) MR images of proximal and distal parts and the magnified images for a girl aged 6.1. (c) Correlation between skeletal age and chronological age for three raters (A1, B, and C). (d) Agreement of rating. Multiple-rater agreement was estimated by calculating the values of Cohen κ for a pair of raters and then computing an average κ for all pairs. (e) Cause-specific ratio of the cases excluded from the rating.