Validity of skeletal age assessment based on phalanges using a portable MRI

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INTRODUCTION

Skeletal age is often evaluated by assessing the maturity of 13 bones in the left hand and wrist. Although plain radiography has been the gold standard for the skeletal age assessment, MRI has recently emerged as an alternative because of its noninvasive nature. In a previous study, we developed a portable hand scanner with a small permanent magnet [1], which requires no shielding room, occupies only a small fraction of the space, and enables skeletal age examination in remote place. However, the available FOV size of the portable MRI is limited and it requires more than one scans to image all the bones necessary for the skeletal age assessment. In this study, we limit the target bones to phalanges which can be imaged in one scan, and assess the skeletal age based on MR images of the phalanges alone. The simplification of the protocol can save scan time and effort for both examination and rating, and would reduce errors from motion artifact in skeletal age assessment.

MATERIALS AND METHODS

A portable system consisted of a C-type Nd-Fe-B permanent magnet (Neomax Engineering, Tokyo, Japan; field strength = 0.306 T, gap width = 8 cm, sizes = 27 × 39.2 × 31 cm^3, weight = 135 kg, and homogeneity = 8.5 ppm over 8 × 8 × 4 cm^3 DEV) (Fig. 1a), a solenoid RF probe, a gradient coil set, a shim coil, and an MRI console. A total of 78 healthy children aged from 3.4 to 15.6 (mean 9.5, 53 boys and 25 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. A 3D coherent gradient-echo sequence (dwell time = 20 μs; TR/TE = 40/11 ms; FA = 60°; matrix size = 256 × 128 × 16; FOV = 10 × 10 × 2.5 cm^3, total acquisition time = 1 min 22 s) was used for imaging phalanges. Skeletal age was rated independently by two raters (an orthopedic surgeon A and a radiologist B) who were blinded to the children's age, according to the Tanner–Whitehouse (TW2) 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). A rater assigns a maturity stage by two methods; 1) assessable bones obtained with portable MRI and 2) 13 bones obtained with hand MRI (Fig. 1b). It is necessary for all 13 bones for the original TW2 method to calculate skeletal age. In method 1), however, since a part of bones were not imaged with the portable scanner and could not be assigned, we used an extrapolation method to estimate skeletal age, taking into account the weighting factor for the score of each bone. Skeletal age was independently rated by A and B. The rater A rated twice (A1 and A2) for intrarater reproducibility. For comparison, in method 2), all 13 bones were imaged for the same subjects using a hand MRI with a 0.3 T permanent magnet (Fig. 1b) [2]; the distal and proximal parts were imaged separately, and skeletal age was again independently rated by A and B according to the original TW2 method.

RESULTS AND DISCUSSION

Figure 2 shows examples of MR images acquired with the portable scanner. Seven assessable bones (epiphyses) were clearly imaged. Figure 3 shows skeletal age rated using images acquired with the portable MRI as a function of chronological age. The correlation between the skeletal age and chronological age was high (Peason's R = 0.899 for A1, 0.882 for A2, and 0.933 for B). The interrater and intrarater reproducibilities were also high (R = 0.937 (A1 vs. A2), 0.919 (A1 vs. B), and 0.922 (A2 vs. B). The rated skeletal ages were compared with those rated based on images of all bones acquired with the hand MRI (Fig. 4). Although the correlation between the skeletal ages rated with the two methods was not low, there was a significant difference, especially for young subjects aged below 10. Indeed, the mean skeletal age younger than 10 with portable MRI was obviously high (portable(A1)-hand(A) = 0.68±0.37 years, portable(A2)-hand(A) = 1.06±0.40, and portable(B)-hand(B) = 0.84±0.32).

The high inter- and intra-rater reproducibilities demonstrate the validity of the skeletal age assessment in one scan using the portable MRI. However, there is a discrepancy between phalanx-based and all-bone-based ratings. This is possibly because of excluded bones (ulna and/or radius) in portable MRI. Especially, the ulna has a high weighting factor (~20%) for scoring in the original TW2 method. Since the ulna is matured slowly than the other bones at a young age, the lack of the ulna in phalanx-based rating could lead to overestimation of the skeletal age. To examine this assumption, we chose several patterns of bones for scoring (Fig. 5) and simulated the skeletal age based on data acquired with the hand MRI. Figure 5 shows the mean of difference of simulated skeletal age for each pattern from that rated using all bones (pattern I). The pattern VI corresponds to the bones imaged with the portable MRI in this study. The mean of difference was positive, which agrees with the current experimental result. For the pattern U- where only the ulna was excluded from rating, the mean of difference was almost equal to that for the pattern VI, whereas the pattern R- including the ulna showed the negative effect. This indicates that the exclusion of the ulna is the main cause of errors and supports the above assumption. To obtain the more accurate value of skeletal age, a correction method considering overestimation due to the lack of the ulna is required.

In conclusion, we verified the skeletal age assessment based on phalanges using the portable MRI.

REFERENCES: [1] Y. Terada et al., Development of a Portable Wrist MRI for Skeletal Age Assessment, ISMRM Proc. 2761 (2013). [2] Y. Terada et al., Skeletal Age Assessment Using a New Dedicated Hand MRI System for Young Children, ISMRM Proc. 1685 (2013).

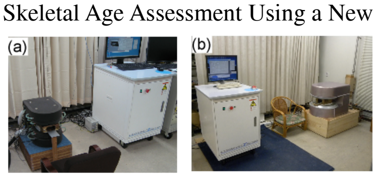


Fig. 1. (a) Portable MRI with a 0.3 T permanent magnet (135 kg). (b) Hand MRI with a 0.3 T permanent magnet (450 kg).

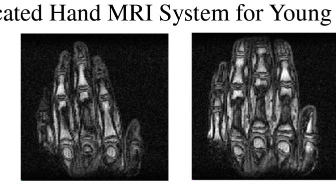


Fig. 2. MR images acquired with portable MRI (left: 7.7 years, girl, right: 10.4 years, girl).

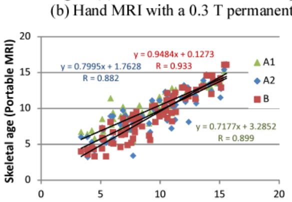


Fig. 3. Skeletal age rated from MR images acquired with portable MRI as a function of chronological age.

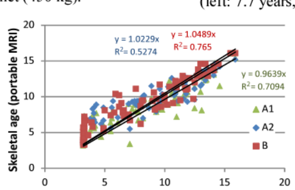
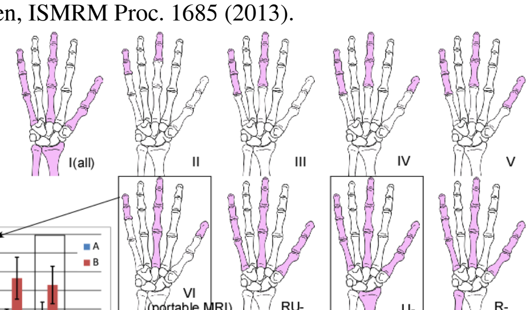


Fig. 4. Comparison of skeletal ages rated using phalanges imaged with portable MRI and those rated using all bones imaged with hand MRI.



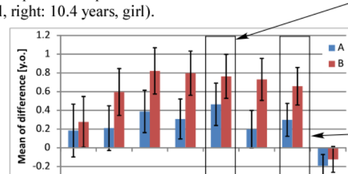


Fig. 5. Mean of difference in skeletal age simulated using different pairs of bones. The bones used for rating were colored in pink. The pattern VI corresponds to phalanges which could be imaged with portable MRI. The error bar corresponds to 95% confidence intervals.