Automatic prospective registration of high resolution trabecular bone images of the tibia

J. H. Blumenfeld[1,2], J. Carballido-Gamio[1], R. Srinivasan[1], I. Hancu[3], D. J. Blezek[3], S. Majumdar[1]

[1]Department of Radiology, University of California, San Francisco, San Francisco, California, United States, [2]Department of Bioengineering, UCSF-UCB Joint Graduate Group in Bioengineering, Berkeley, California, United States, [3]GE Global Research Center, Niskayuna, New York, United States

Introduction:

Techniques to improve image registration precision by adjusting scanning parameters prior to image acquisition have been reported in recent scientific literature [1,2] Investigators have created a registration technique for proton magnetic resonance spectroscopy of brain longitudinal exams to track disease progression [3]. This technique utilizes a mutual information registration algorithm [4] to register images in a baseline and follow-up exam. The output of the registration algorithm, three translations and three Euler angles, is then used to redefine the region to be imaged and thus to acquire an identical oblique imaging volume in the follow-up exam as in the baseline. This pre-registration has provided improved region overlaps as well as generally decreased short-term measurement variability and improved workflow. An adaptation of this methodology that can be applied to musculoskeletal magnetic resonance imaging longitudinal studies would be of significant importance. This would be especially significant in high resolution joint imaging, for characterizing trabecular bone or articular cartilage. For example, when imaging trabecular bone in osteoporosis, the regional variations in structure of bone is inherent and follow up images registered to the baseline scans would have profound impact on the quantitative evaluation of trabecular bone. It would enhance the precision of measurements such as apparent bone volume to total volume fraction, apparent trabecular number, apparent trabecular spacing, and apparent trabecular thickness.

Materials and Methods:

Images of the tibia were obtained using a 3T (GE Signa) MRI scanner using a quadrature knee coil. After a three-plane localizer, two baseline scans were obtained. The first baseline scan was in the axial plane using a fast SPGR sequence with a 256x256 matrix, 12mm FOV, 40º flip angle, 2mm slice thickness and a total of 48 slices. The region covered included part of the calcaneus to facilitate the registration, the scan time was approximately 2 minutes, and the acquisition was denoted as the registration scan. The second baseline scan was intended for quantitative comparison. This acquisition was an axial, high resolution, fast SPGR with a 512x384 matrix, 12mm FOV, 40º flip angle, 1mm slice thickness and approximately 8 minutes of scan time. The volunteers were then removed from the scanner and were repositioned for the follow up scan where after a three plane localizer the registration scan was obtained using the same protocol as in the first baseline scan (~2 minute scan time). Using a mutual information based registration scheme, the low resolution baseline and follow up scans were registered. The registration provided the translation and rotation parameters for the definition of an oblique follow up scan. This final follow up scan was a high resolution scan with the same parameters as the high resolution baseline scan except for input parameters from the registration (~8 minute scan time).

Results:

Fig. 1 shows a representative scan in a 26 year old female volunteer. The improvement from the registration can be seen by looking at the subtraction images (Fig. 1c and g) and corresponding tibia segmentations (Fig. 1d and h). Displayed next to the subtraction images are the baseline low (Fig. 1a) and high (Fig. 1e) spatial resolution scans, and the corresponding follow-up images without registration (Fig. 1b) and with registration (Fig. 1f). The following parameters were the inputs for the final high resolution follow up scan: X rotation = 1.39, Y rotation = 0.34, Z rotation = 3.26, Center R/L = -62.5, Center A/P = -8.1, Start S/I -32.1, and End S/I = 61.9. It can be seen in the results that the second follow up scan is better oriented with the baseline scans. By simple image subtraction and rendering of the segmented tibias the improvement can be assessed. For example, in Fig. 1c the edges of the cortical bone are misaligned with higher intensity in the difference image, and clear separation of the red and green tibial renderings in Fig.1d is visible. In Fig. 1g, the high intensity differences within the tibial edge are reduced, and there is considerable more overlap in the red and green tibial renderings in Fig. 1h.

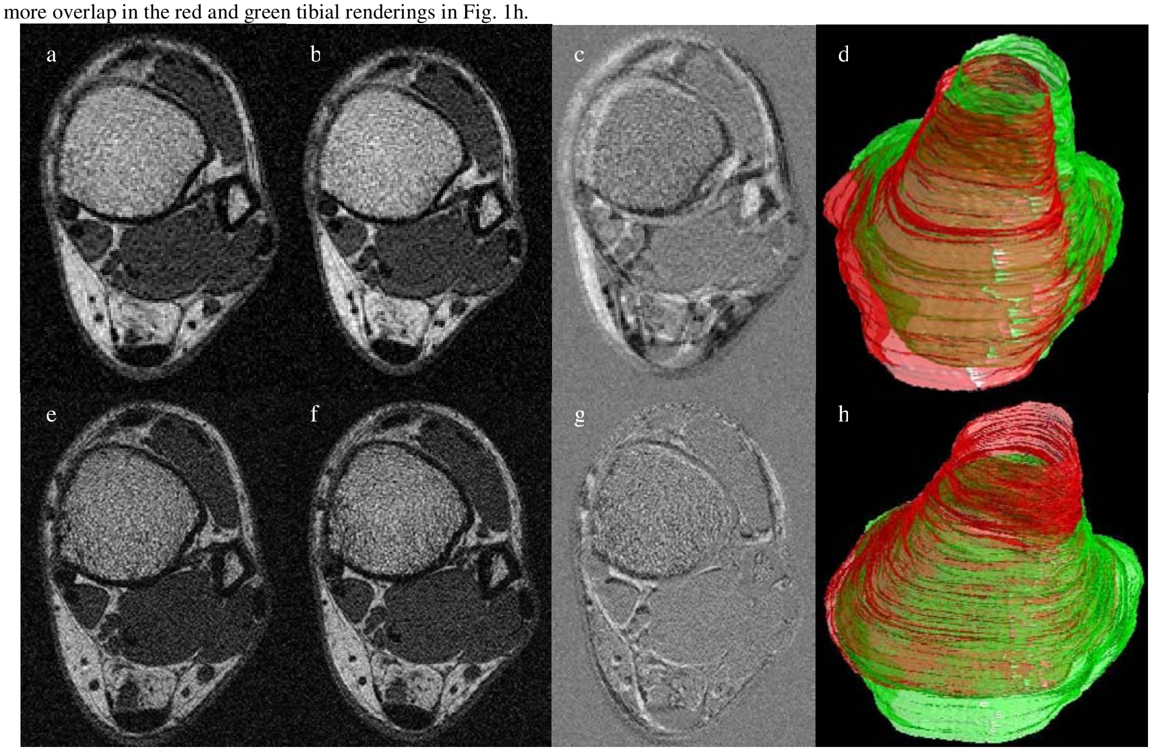

Fig. 1. Comparison of registration versus follow-up without registration. (a) Low spatial resolution baseline. (b) Low spatial resolution follow-up. (c) Subtraction of a and b. (d) Rendering of non-registered tibias (green=low resolution baseline, red=low resolution follow-up). (e) High spatial resolution baseline. (f) Registered high spatial resolution follow-up. (g) Subtraction of e and f. (h) Rendering of registered tibias (green=high resolution baseline, red=high resolution follow-up).

Discussion:

The study of the progression of a disease or the efficacy of a treatment based on MRI requires the proper analysis of corresponding regions of interest in the baseline and follow-up scans. In this work we have demonstrated the feasibility of using a mutual information based method to prospectively register longitudinal MR images of tibia scans. Results suggest that there is a possibility that this algorithm is robust enough to be used in several different musculoskeletal imaging applications including the hip, wrist, or knee as well as the tibia.

References:

1. Chu W-J, et al. *ISMRM, Kyoto*, 2004; 105.
2. Hartmann SL, et al. *Cput. Med. Imag. Graph.* 1998; 22(6):453-461.
3. Hancu I, et al. *NMR Biomed*. 2005 Oct;18(6):352-61.
4. Viola P, et al. *Int J. Comp. Vis*. 1997; 24(2):137-154.