EFFICIENT MRI KNEE CARTILAGE VOLUME ESTIMATION VIA TIBIAL PLATEAU SURFACE REGISTRATION

INTRODUCTION:
Objective assessment of progression of osteoarthritis (OA) in the knee was once limited to measurement of joint space narrowing and associated changes on plain radiographs [1]. With new research focusing on medical and surgical techniques to slow or reverse the OA progression, more sensitive quantification of changes in knee cartilage volume and thickness is necessary. Magnetic resonance imaging (MRI) with fat suppression allows direct observation of cartilage [2]. Several groups have developed techniques to quantify knee cartilage volumes on MRI [3-5]. While highly accurate, these techniques are often laborious and not suited for routine clinical application. Here, we assessed inter-scan accuracy and feasibility of a streamlined approach for efficient knee cartilage volume estimation in normal subjects.

Since tibial cartilage volumes measured by MRI correlate strongly (r = 0.81) with those in the femur, volume measurement may be simplified by considering only part of the knee [6]. Since the medial compartment often shows the most severe arthritis changes in the knee, we further limited volume measurement to this region. The lateral compartment could be measured by the same technique when necessary.

Analyses of cartilage property changes require comparison of MR data acquired at different times. Cartilage volume can be accurately, if tediously, manually re-measured in each new scan [5]. However, if images from successive scans are appropriately registered to the original data set, more rapid direct comparison of cartilage regions is possible. This registration process is itself laborious, particularly if the bone-cartilage interfaces in the entire knee must be digitized as in some algorithms [e.g., 3]. Fortunately, the intercondylar eminence of the tibia offers a uniquely shaped surface that can be accurately registered using relatively few landmarks. With these simplifications, the volume of a key portion of knee cartilage can be efficiently calculated.

METHODS:
Patients: Nine healthy subjects (5 male), aged 23-48, with no symptoms or signs of OA, had scans of one knee (3 left, 6 right) performed twice on different days within an interval of up to two weeks.

Imaging: Sagittal T1-weighted fat-saturated MRI was performed using standard clinical protocol in a 1.5 Tesla scanner, with voxel size = 0.31 x 0.31 x 1.0 mm.

Registration: Points on the proximal tibial surface at the intercondylar eminence were digitized manually using commercial software (SliceOmatic, TomoVision, Canada; Fig. 1). Due to high resolution images, no point resampling was required prior to surface modeling into triangular patches. Surface matching was then performed by a fully automated algorithm that did not require points to correspond directly to each other [7]. Each of a cloud of points representing the first surface was applied to the second surface by minimizing the summation of the squared normal distances between modelings into triangular patches. Surface matching was then performed by a fully automated algorithm that did not require points to correspond directly to each other [7]. Each of a cloud of points representing the first surface was applied to the second surface by minimizing the summation of the squared normal distances between modelings into triangular patches. Surface matching was then performed by a fully automated algorithm that did not require points to correspond directly to each other [7]. Each of a cloud of points representing the first surface was applied to the second surface by minimizing the summation of the squared normal distances between surface was matched to a conjugate patch from the second surface by

RESULTS:
Registration between scans was accurate to an RMS error of 0.121 mm (Table 1). Resulting cartilage volumes were accurate to 294+/80 mm³ (1.3+/-3.2%, mean +/- standard deviation, SD) between scans, with a maximal difference of 186 mm³ (5.5%).

DISCUSSION:
Cartilage loss in OA is thought to occur at up to 5% per year [6]. Inter-scan accuracy (coefficient of variation 3.2%) of this technique for rapid cartilage volume estimation was comparable to that of other groups [3, 4], and only slightly higher than the estimated daily variation in cartilage volume due to loading and hydration (~1.6%) [9].

This technique could form a clinically useful intermediate between rudimentary radiographic estimation of cartilage thickness and other more elaborate MRI-based techniques. As monitoring of OA progression by measurement of cartilage volumes on MRI moves from research trials to widespread clinical use, we envision a few minutes of a trained technologist’s time to segment the cartilage in an initial scan, with almost entirely automated calculation of cartilage volume in subsequent scans. Future work by our group will include assessment of accuracy and inter-observer reliability of our technique in patients with established OA.