DISTRIBUTION OF ARTICULAR CARTILAGE THICKNESS IN PRE- AND ADVANCED OSTEOARTHRITIC JOINTS WITH HIP DYSPLASIA: A FULLY AUTOMATED COMPUTER ANALYSIS OF 3D MR IMAGING

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Introduction: Assessment of articular cartilage thickness distribution is important for localization of osteoarthritic development and determination of subsequent surgical therapy. Among various imaging modalities, magnetic resonance (MR) imaging showed superior clinical usefulness for evaluation of three dimensional (3D) cartilage thickness in knee joints, however, few studies have been conducted in hip joints. The purpose of this study is to evaluate 3D distribution of acetabular articular cartilage thickness in patients with hip dysplasia, and clarify the mechanism of osteoarthritic development using MR imaging. To perform accurate and reproducible assessment of cartilage thickness, a fully automated computer analysis system in cartilage segmentation and subvoxel measurements of imaging resolution has been developed.

Material and Methods: Twenty-two dysplastic hips of 18 patients and 5 normal volunteer hips were studied. On anteroposterior radiographs of the patients, center edge (CE) angle ranged from -4 to 22 degrees. Fifteen hips showed wide joint space (normal hips), pre-ostearthritic hips, and advanced ostearthritic hips. Maximal cartilage thickness of the volunteers, on the contrary, showed a characteristic distribution with advanced ostearthritic hips, on the contrary, showed a remarkable increase of cartilage thickness was not observed in normal hips. The thickness over the entire acetabular cartilage area was automatically detected from the radial directional derivative images rendered. The method consisted of the following four steps. 1) The center of a sphere that approximates the femoral head was automatically determined using the Hough transform, based on the properties that the gradient vector of the MR volume at the boundaries of the femoral head is aligned from the femoral head center to the voxel positions, and the magnitude of the gradient vector is large. 2) Cartilage regions and the cartilage-bone interface were enhanced using the first and second directional derivatives along radial directions originating from the sphere center determined in the previous step. 3) Acetabular cartilage was automatically detected from the radial directional derivative images using adaptive thresholding. 4) A subvoxel zero-crossing search was performed along the radial directions, and the thickness of the acetabular cartilage was measured from the distance between the inner and outer cartilage edge positions.

To demonstrate the acetabular cartilage thickness distribution, the global coordinate system was used for the acetabulum: the center point of the globe was the center of the femoral head. The acetabular fossa corresponded to 90 degrees of latitude (the North pole), the posterior pole of the acetabulum to 0 degrees of latitude and 180 degrees of longitude, and the anterior pole of the acetabulum to 0 degrees of latitude and 270 degrees of longitude. The cartilage thickness distribution was compared between pre-osteoarthritic hips, advanced ostearthritic hips, and normal hips.

Results: A representative case of cartilage distribution with surface rendering was shown in Fig. 2. Average acetabular cartilage thickness of the volunteers, patients with pre-osteoarthritic hips, and patients with advanced ostearthritic hips was 1.3 mm, 1.7 mm, and 1.8 mm, respectively. All normal hips showed almost homogenous cartilage thickness over the entire acetabular cartilage area. (Fig. 3). Pre-osteoarthritic hips, on the contrary, showed a characteristic distribution of cartilage thickness. Cartilage thickness increased remarkably around the area of 180 to 230 degrees of longitude and the 15 to 30 degrees of longitude (anterosuperior portion of the acetabulum). However, those remarkable increase of cartilage thickness was not observed in advanced ostearthritic hips. Maximal cartilage thickness of the volunteers, patients with pre-osteoarthritic hips, and patients with advanced ostearthritic hips was 2.1 mm, 4.7 mm, and 3.4 mm, respectively. There were statistically significant differences between the volunteers and patients with pre-osteoarthritic hips (p<0.05, Sheffe test).

Discussion: Distribution of cartilage thickness of the hip joint had been studied in cadavers using a needle probe or ultrasound, however, assessment in vivo hip joints, especially in dysplastic hips, had been difficult. In the present study, detailed distribution of cartilage thickness could be evaluated using non-invasive 3D imaging and a custom-made automated computer analytic technique. From this study, several important findings were obtained. First, cartilage thickness varied considerably with respect to the location of the acetabulum in dysplastic hips, and there were a general trend of thick articular cartilage at the anterosuperior portion. Second, decrease of cartilage thickness was likely to occur at the anterosuperior portion, as the osteoarthritic change progressed. These findings suggested that observation of cartilage abnormality change is most important in evaluation of osteoarthritic change for dysplastic hips. Further, inhomogenous distribution of cartilage thickness may be taken into account to achieve satisfactory cartilaginous congruency when periacetabular osteotomy is performed.

Fig. 1 (left): Original sagittal MR image in patients with dysplastic hips. Fig. 2 (right): Surface of rendering of 3D acetabular cartilage

Fig. 3 (Upper): Cartilage distribution of normal hips. (Below): Cartilage distribution of dysplastic hips. Horizontal axis: longitude degrees, Vertical axis: latitude axis.