Contrast Enhanced Imaging of Human Meniscus Using Cone Beam CT

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Disclosures:

Introduction: Menisci absorb shocks and stabilize the knee joint [1]. Meniscal injuries can lead to mechanical overloading of articular cartilage and eventually to knee osteoarthritis (OA) [2, 3]. Hence, immediate detection of meniscal injury is important for successful treatment and prevention of OA. Contrast enhanced computed tomography (CECT) imaging has been proposed for detection of injuries and degeneration of cartilage [4]. Recently, the technique was successfully applied with bovine meniscus in vitro [5]. In the present study, we evaluate for the first time the potential of CECT to image contrast agent diffusion in human menisci utilizing peripheral clinical cone beam computed tomography (CBCT) scanner.

Methods: Total of 26 menisci were acquired from the left knee joints of human cadavers (n=13, age 24-76) with no history of joint disease (permission from the National Agency of Medicolegal Affairs, Helsinki, Finland; permission 1781/32/200/01). Diffusion of anionic (q=−1) contrast agent (HexabrixTM, Mallinckrodt Inc., St. Louis, MO, USA) into the meniscus was studied using a modern clinical CBCT scanner (Verity, Planmed Oy, Helsinki, Finland). The diffusion of contrast agent to meniscus was imaged at 16 different time points up to 30 hours. Between imaging session, the menisci were immersed in isotonic bath (700 ml) of phosphate buffered saline (PBS, including proteolytic inhibitors and antibiotics) containing contrast agent (48 mgI/ml). CBCT images were acquired with isotropic voxel size of 200×200×200 µm³ and 96 kV tube voltage. After 30 hours, the contrast agent was washed out by immersing the menisci in PBS for 24 hours. CT data was analyzed using Analyze software (v. 10.0, AnalyzeDirect, Inc., KS, USA) and MATLAB (r2011a, MathWorks, Inc., Natick, MA, USA). The images were segmented using a semi-automatic threshold based algorithm and the meniscal tissue was isolated for further analysis. Next, the meniscus was divided into three regions of interests (ROIs): anterior, central and posterior; each region one third of the total length of the meniscus. At each time point, the mean X-ray attenuation for each ROI was obtained by averaging the Hounsfield unit (HU) values over all pixels within the ROI. The mean partition of the contrast agent was determined by subtracting the non-contrast images from those with the contrast agent and normalizing with the mean HU value of the contrast agent bath.

For histological analysis, 3µm thick sections were cut. These sections were stained with Safranin-O and imaged with a light microscope (AxioImager M2, Carl Zeiss, Oberkochen, Germany). Spatial concentration of Safranin-O stain is known to reflect the proteoglycan (PG) concentration in cartilage tissue [6].

Results: Mean contrast agent partition varied from 53% to 78% after 30 hours of diffusion. In most samples, contrast agent diffusion reached equilibrium after 25 hours (Fig. 1A, B, C). Figure 1D shows the contrast agent partition in meniscus after 30 hours of diffusion, qualitatively indicating spatial agreement of PG content and Safranin-O staining.
Discussion: This study demonstrates the potential of the CECT for imaging of human meniscus. The cross-sectional distribution of contrast agent was found to be consistent with that reported in a previous µCT study on bovine meniscus [5]. Importantly, the resolution of a clinical CBCT scanner was found sufficient. The time required to reach diffusion equilibrium (>25 h) is not practical for clinical application. However, as shown with cartilage with 45 min diffusion time [7], shorter delay between injection and imaging could also be feasible in diagnostics of meniscal pathologies. Meniscal tears may be detected in arthrographic images acquired immediately after administration of contrast agents, while detection of degeneration of internal structures could require longer (e.g. 45 min) delay.

Significance: CECT has shown clinical potential in detection of cartilage injuries and degeneration in vivo [7]. Based on the present results, CECT may have potential also for clinical diagnostics of meniscal pathologies.

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