DUAL CONTRAST CT METHOD ENABLES DIAGNOSTICS OF ACUTE CARTILAGE INJURIES USING A SINGLE CT IMAGE
Annina EA Saukko (1,2), Juuso TJ Honkanen (1,2), Wujun Xu (1), Sami P Väänänen (1,3), Jukka S Jurvelin (1), Vesa-Pekka Lehto (1), and Juha Töyräs (1,2)

(1) Department of Applied Physics, University of Eastern Finland, POB 1627, FI-70211, Kuopio, Finland,
(2) Diagnostic Imaging Center, Kuopio University Hospital, POB 100, FI-70029, Kuopio, Finland,
(3) Department of Orthopaedics, Traumatology and Hand Surgery, Kuopio University Hospital, POB 100, FI-70029, Kuopio, Finland

Introduction
Articular cartilage damage caused by a sudden accidental mechanical impact, e.g., a fall or sports accident, is a relatively common injury. Such injuries and related tissue degeneration can be detected using contrast-enhanced computed tomography (CECT) [1] which currently relies on two subsequent scans at 0-minute (arthrography) and 45-minute (delayed arthrography) time points. Injured tissue is recognized by observing the variations in the distribution of anionic contrast agent within the tissue [2]. The first scan allows segmentation of articular surfaces and surface lesions while the latter enables detection of injury-related post-traumatic degeneration [1, 3]. 45 minute time point for delayed arthrography has been shown to be optimal for the evaluation of lesion severity [4]. However, the accurate segmentation of articular surfaces from the delayed arthrography scan is impossible due to contrast agent diffusion-induced loss in contrast at surfaces. To solve this problem, we introduce a new dual contrast agent, i.e., a mixture of anionic contrast agent (ioxaglate) and bismuth(III) oxide nanoparticles (BiNPs), for CECT imaging of cartilage.

Methods
In this dual contrast agent, BiNPs are hypothesized to induce a high contrast at articulating surface at all time points as they are physically too large to diffuse into cartilage. Instead, ioxaglate diffuses into cartilage and reveals structural and compositional integrity of cartilage matrix. The feasibility of the dual contrast agent is investigated using intact, enzymatically (trypsin) degraded, and mechanically injured osteochondral samples (N=3x10). The samples are imaged with microCT scanner (Bruker SkyScan 1172) immediately and 45 minutes after contrast agent immersion.

Results
As hypothesized, depth-wise X-ray attenuation profiles (Figure 1) demonstrate that BiNPs were unable to diffuse into cartilage. This produce high contrast at synovial fluid-cartilage interface even at 45 minutes after immersion. Dual contrast method also enabled accurate segmentation of cartilage and detection of superficial cracks in articular surface. Furthermore, tissue damage was sensitively detected as ioxaglate uptake was significantly greater (P=0.005) into mechanically and enzymatically injured samples than into the intact samples.

Discussion
To conclude, the dual contrast method enables simultaneous segmentation of articular cartilage layer and detection of injuries and degeneration using only a single CT scan conducted 45 minutes after administration of the dual contrast agent. Further, this method will improve the logistics of clinical application, reduce the patient radiation dose by 50%, and eliminate the need for often laborious co-registration of the CT image stacks.

References

Acknowledgements
Academy of Finland (Projects 269315 and 288531), Kuopio University Hospital (VTR 5041746, FY 210), and Magnus Ehrnrooth Foundation are acknowledged for financial support.