CONTRAST-ENHANCED X-RAY IMAGING: PRELIMINARY RESULTS ON REVERSIBILITY OF EFFECT OF A CATIONIC AGENT ON MECHANICAL PROPERTIES OF ARTICULAR CARTILAGE

Simone Fantoni[1], Matteo Berni[1], Giulia Fraterrigo[2,3], Roberta Fognani[1], Fabio Baruffaldi[1], Paolo Cardarelli[4], Angelo Taibi[5], Massimiliano Baleani[1]

[1]Medical Technology Laboratory, IRCCS Istituto Ortopedico Rizzoli, Bologna, Italy
[2]BIC Laboratory, IRCCS Istituto Ortopedico Rizzoli, Bologna, Italy
[3]Department of Mechanical and Aerospace Engineering, Politecnico di Torino, Turin, Italy
[4]Istituto Nazionale di Fisica Nucleare (INFN), Division of Ferrara, Ferrara, Italy
[5]Department of Physics and Earth Sciences, University of Ferrara, Ferrara, Italy
Email: simone.fantoni@ior.it

Summary

Contrast agents (CAs) enhance the X-ray visibility of articular cartilage (AC), potentially enabling its quantitative evaluation through low-dose high-resolution imaging systems (i.e., HR-pQCT). The aim of this study was to investigate the reliability of using a cationic CA by investigating the correlation between parameters extracted from diagnostic imaging and mechanical properties of AC. However, detrimental effects of CAs on AC should also be considered. Therefore, the reversibility of the effect of the cationic CA on the mechanical properties of AC was also evaluated.

Introduction

The AC plays a crucial role in deploying multiaxial forces arising by locomotion. The interrelations between AC composition and mechanical response are essential to understand the onset and progression of degenerative processes. High-resolution contrast-enhanced computed tomography can quantify proteoglycans (PGs) using CAs affine to them. The aim of this study was to investigate the correlation between parameters extracted from diagnostic imaging achieved using an iodine-based cationic CA (CA4+) [1], and mechanical properties of AC. Since CA4+ significantly alters both the instantaneous and at-equilibrium mechanical response of AC [2], which is undesirable for clinical applications to avoid any adverse effects on AC [3], this study also assessed the reversibility of CA4+ impact on the mechanical properties of AC.

Methods

Paired osteochondral cores (OCs, ∅=10mm, h=10mm) were harvested from bovine stifle joints. OCs underwent indentation test, i.e., 15%-maximum nominal deformation, 0.15s-1-strain rate, 6-mm spherical indenter, 300s-long relaxation [4]. The indentation protocol consisted of three test repetitions, each performed 40 min apart. Samples were subdivided into control and treated groups, exposing their AC to phosphate-buffered saline (PBS) and CA4+ bath, respectively, for 22h at room temperature [1]. Treated OCs were acquired by a clinical HR-pQCT (XtremeCT II, SCANCO Medical AG, 60-µm isotropic voxel size) to evaluate the CA4+ distribution within AC. Afterwards, both groups were exposed to a dynamic washout (PBS, room temperature) for 22h. The indentation protocol was then repeated on both groups to compare the instantaneous, viscous and at-equilibrium behavior of AC. Hayes and stretched exponential models were used to estimate AC elastic (instantaneous E_0 and equilibrium E_{eq} modulus) and viscous (time constant τ and stretching parameter β) parameters, respectively.

Results and Discussion

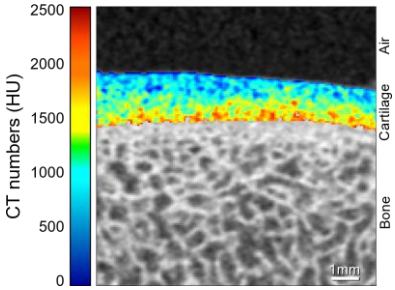

Figure 1: Reconstructed HR-pQCT image of AC with CA4+.

Correlations were found between AC thickness combined with mean attenuation (Figure 1) and viscoelastic parameters (E_0: ρ=0.80, $p<0.001$; τ: ρ=0.75, $p<0.001$). Collected data confirm that exposing AC to CA4+ significantly decreased the instantaneous and at-equilibrium response comparing to control group (E_0: -24%, $p<0.001$; E_{eq} -44%, $p<0.001$). However, after washout, the difference between the treatment and control groups was no longer significant. The CA4+-induced softening of AC could be addressed to a decreased pre-tensioning of extracellular matrix due to a partial shielding of PG charge density, acted by CA4+. Nevertheless, the preliminary data suggest for a reversibility of such effects, supporting the hypothesis of a non-covalent nature of PGs-CA4+ interaction.

Conclusions

Results from CA4+-enhanced HR-pQCT correlated significantly with mechanical parameters from indentation tests. Owing to the softening related to CA4+ exposure, any load on treated AC should be avoided. Nevertheless, such softening reverses with CA4+ washout. The reliability, impact and reversibility of CA4+-enhanced HR-pQCT will be studied on AC models alternative to bovine (i.e., human).

Acknowledgments

The study was carried out thanks to the fundamental contribution of the Fondazione del Monte di Bologna e Ravenna.

References

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