MRI and MRM of Non-Newtonian Gels

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Introduction

Hydrogels have been proposed as an alternative substrate to polymer micro-particles for use in biological 3D printing applications because they offer improvements in ultimate achievable resolution and better maintain the shape of printed constructs [1]. These properties make hydrogels particularly attractive for tissue engineering applications as they also offer a water-based medium appropriate for the deposition, maintenance and growth of living tissue. Due to the high water content of hydrogels (95%-98%) and soft tissues (65%-83%), non-invasive, proton-based MRI is an obvious choice for imaging live constructs. Also, diffusion properties and biologically relevant nuclei (including ^{1}H, ^{13}C and ^{31}P) can be used as tools for assessing viability and quantifying metabolism with MR [2,3]. The goal of this work was to characterize the contrast properties of hydrogels and signal stability of living samples using common MR imaging protocols.

Experimental

Cellular constructs of colorectal origin and biopsies from osteosarcoma were deposited (0.4mm dia. printing nozzle) or suspended respectively in hydrogel matrix containing cellular growth factors. Live samples underwent single Spin-Echo (TE/TR = 8.5/1500ms, res = 31μm in-plane, slice thickness = 100μm, avg = 6, total scan time = 38min) and multiple diffusion weighted imaging protocols (TE/TR = 18/3000ms, b = 1000s/mm^2, res = 55μm in-plane, slice thickness = 250μm, avg = 4, total scan time = 26min) over a 22.5h interval to determine their contrast and signal stability characteristics.

Results and Discussion

Sufficient T2 contrast was achieved between live constructs and hydrogels to allow for visualization of the suspended biopsy samples **Fig.1.** Diffusion-weighted signal in the time course experiment was static in the hydrogel material but varied considerably between the first and second time points (0-11h) of the diffusion experiment **Table1**.

Conclusions

Diffusion signal measurements in the hydrogel matrix suggest a relatively static environment and indicate consistency in MR scan performance over time. Alternatively, the observed signal drop in the deposited cells indicates a rapidly occurring (within 11h) increase in diffusivity. Such changes are often associated with an increase in the porosity of plasma membranes. Subsequent experiments include 3D printing of live cell constructs onto Bruker's RF surface microcoils to attain MR images at cellular-level resolutions (<10μm isotropic) and perfusion system trials to improve the time course over which samples are viable.

Acknowledgements

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References

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Table I Signal to noise ratios (SNR) calculated from the time course diffusion-weighted image series of colorectal cells deposited in hydrogel. Diffusion signal decreases dramatically during the first interval (0-11h) and reaches steady state conditions after (11-22.5h).

Time Point (h)	Hydrogel SNR	Colorectal Cell Mass SNR (normalized)
0.0	17.60	31.85
11.0	17.03	19.44
16.0	16.8	18.59
22.5	15.32	19.67

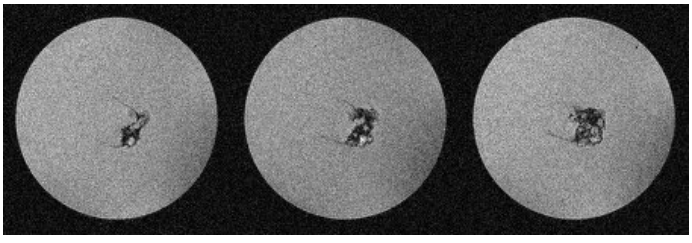

Fig.1 Representative Spin-Echo MR images (31μm x 31μm x 100μm) of live biopsies from osteosarcoma. T2-weighted MR contrast is sufficient to distinguish the cancerous tissue and its internal structure from the surrounding hydrogel matrix.