Incorporating Fluorescent Nanoprobe Emulsions in Hydrogels for Non-invasive Oxygen Measurement

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Abstract

The goal of the project was to test nanoprobe retention once they have been incorporated into the hydrogels. The nanoprobe was a nanoemulsion comprised of 5% HS-15 surfactant, 40% Polydimethylsiloxane (PDMS), 55% DI water, and 0.1 millimolar of Nile red solution. The nanoprobe was crosslinked with dithiothreitol (DTT). One problem with macroencapsulation is that the cells we are using are very oxygen dependent and without the proper levels of oxygen will experience hypoxia and die. Therefore, our lab is developing a non-invasive method of detecting in live subjects. The siloxane nanoprobe gives off a detectable signal when scanned through an H-MRI technique based off the volume of oxygen in the surrounding area around the nanoparticles within the hydrogel. The siloxane nanoparticles are extremely oxygen dependent, which means that cell survivability is directly proportional to the oxygen surrounding the cells. By tracking the oxygen levels within the hydrogel, the Weaver lab has a means of monitoring the cells within the patient.

Methods

The goal of the project was to test nanoprobe retention once they have been incorporated into the hydrogels. The nanoprobe was a nanoemulsion comprised of 5% HS-15 surfactant, 40% Polydimethylsiloxane (PDMS), 55% DI water, and 0.1 millimolar of Nile red solution. The nanoprobe was crosslinked with dithiothreitol (DTT). One problem with macroencapsulation is that the cells we are using are very oxygen dependent, which means that cell survivability is directly proportional to the oxygen surrounding the cells. By tracking the oxygen levels within the hydrogel, the Weaver lab has a means of monitoring the cells within the patient.

Conclusion

According to the data that was gathered by both the image analysis and the plate reader, it can be inferred that there is no significance to the nanoprobe discharge from the hydrogels across all three concentrations. The initial release on the first day is indicative of having excess nanoprobe that failed to be encapsulated in the initial cross-linking process and as a result causes the high release on the first day. This combined with the image analysis data which indicates that there was still a significantly higher fluorescence value than that of the control sample, shows that there the encapsulated nanoprobe successfully remained in the hydrogel.

Background

Diabetes is an ever-increasing issue that affects more and more people each year. The number of people diagnosed with diabetes each year has increased from 108 million in 1980 to 422 million in 2014. In 2016 alone, around 1.6 million deaths were attributed to diabetes while another 2.2 million deaths were caused by high blood glucose in 2012 [1]. The aim of our lab is to develop a new method of type 1 diabetes treatment through cell transplantation. Using hydrogels, we seek to transplant insulin-secreting cells into diabetic patients, which could potentially eliminate complications of diabetes.

Hydrogels are primarily a water-based network of hydrophilic polymers that have a variety of uses in the realm of biomaterials such as mimicking microenvironments or drug delivery. Our hydrogels are a synthetic poly(ethylene glycol) (PEG)-based system used to macroencapsulate cells to protect them from the recipient immune system. Our PEG hydrogels were crosslinked with dithiothreitol (DTT). One problem with macroencapsulation is that the cells we are using are very oxygen dependent and without the proper levels of oxygen will experience hypoxia and die. Therefore, our lab is developing a non-invasive method of detecting the oxygen levels surrounding these transplanted cells. We aim to employ a siloxane nanoprobe to detect the oxygen levels surrounding the cells. Using a special H-MRI technique of detection the nanoparticles will return a signal that corresponds to the level of oxygen in that location. Nanoprob es are already used in a variety of medical applications, such as in the targeting of tumor growths to monitor and enhancing MRI contrast [2]. Since cell performance is dependent on oxygen they are surrounded by, this allows us a non-invasive means of detecting and tracking cell performance in a patient.

Results

The results of the experiment indicated that there was a high immediate release of nanoprobe from the 10%, 4%, and 2% nanoprobe concentrations, followed by a small release across the following days the experiment was recorded. After day 2 each of the fluorescence values fell below the control gel in their levels of detectable fluorocence. This is further supported by the compiled image data which indicates that there was still a significant amount of detectable fluorescence within the hydrogel images higher than the control fluorescence.

Future Work

The next step for this project would be to evaluate the nanoprobe signal in gels using H-MRI techniques. The Weaver lab collaborates with the Kodibagkar lab who performs the MRI tests and calculations. To accomplish this task, we will be working in tandem with the collaborator, and adjusting the gels depending on the results from the different MRI experiments that our collaborator performed. The end goal of the use of these nanoparticles is to be able to accurately and continuously quantify the oxygen levels in a given region of tissue surrounding a hydrogel. This would be invaluable information for finding the best possible transplantation site as well as having a means of noninvasively monitoring the oxygen consumption rates of the cells within a subject.

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References