Changes in Properties of Polyvinyl Alcohol when Prepared under a Deoxygenated Environment

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Introduction

There are several materials currently used as tissue mimicking phantoms depending on the imaging modality in question. Poly(vinyl alcohol) cryogel (PVA-C) not only has the potential to be used as a multi-modality phantom, but it also has a variety of biomedical advantages, including its non-toxic, non-carcinogenic and biodegradable characteristics (1). This polymer is easily produced and readily modified with electric, elastic and MRI properties shown to be comparable to that of human tissue (2-4).

In an effort to control various factors during the process of PVA-C manufacture, our group implemented a procedure where the PVA formulation process was carried out in an inert gas (nitrogen) environment. The amorphous regions of PVA-C act as a reservoir for water, in which oxygen gas readily dissolves. Since oxygen is paramagnetic, the magnetic resonance imaging (MRI) relaxation times, T_1 and T_2, of PVA-C manufactured in the presence of oxygen may hypothetically differ from those prepared in deoxygenated (nitrogen) conditions. The following study investigates the novelty of PVA-C as a tissue mimicking phantom by exploring the MR relaxation times of the cryogel prepared in a deoxygenated environment. The variation in the MRI properties will serve as an indicator of how dependent the MRI signal is on paramagnetic oxygen**.**

Methods

A 15% (w/w) PVA solution was prepared by adding 45g of PVA (MW 124,000 – 164,000; Aldrich 36316-2) to a flask containing 255-mL of distilled water. A nitrogen supply attached to the flask was initiated for 2 minutes in order to purge the air from inside the flask, thereby creating an oxygen-free environment**.** The remaining oxygen in the PVA solution was removed by heating and stirring the solution for 15 minutes, followed by an additional 2 minute nitrogen purge. The solution was then heated for 2 hours at 90° C to form a PVA hydrogel solution**,** which was injected into cylindrical cavity moulds and subjected to either 3- or 6-freeze/thaw cycle(s) (FTC) in a temperature controlled (–20 ºC to +20 ºC; 0.1 ºC per minute) ethylene glycol bath. The samples were then removed and stored in distilled water and thereafter referred to as PVA-C(N). The aforementioned procedure was then repeated, except the nitrogen purge was not performed and these samples were referred to as PVA-C.

Image based measurements of T_1 & T_2 were performed using custom built 1T, 1.89T, and 3T MR systems. T_1 was measured using a 2D inversion recovery imaging sequence repeated with 8 different inversion times (TI), spaced from 20 to 1000ms. T_1 maps were created using pixel by pixel non-linear least square fit to the equation $S = K[1-2\exp(-TI/T_1)]$, then an ROI was drawn and the average T_1 was calculated using the variation across the ROI. T_2 was measured using a spin echo imaging sequence repeated with 6 different echo times (TE), which were spaced from 25 to 500ms. T_2 maps were created using pixel by pixel log-linear least square fit, an ROI was drawn and the average T_2 was calculated using the variation across the ROI.

Results

The effects on the MR relaxation times due to the introduction of nitrogen are shown in Figures 1 and 2. T_1 significantly increased ($p<0.05$) with increasing field strength for the PVA-C samples, whereas there was no significant increase for the PVA-C(N) samples. T_2 showed no significant increase for either PVA-C or PVA-C(N) with increasing field strength. The 6 FTC samples showed similar results to PVA-C(N) for T_1 and T_2.

Discussion

PVA-C showed a field dependence in T_1 for both the 3 and 6 FTC samples. However, the introduction of nitrogen caused a loss of T_1 field dependence for both the 3 and 6 FTC samples. This loss was the result of the removal of paramagnetic oxygen within the sample. No field dependence in T_2 was shown for either PVA-C(N) or PVA-C. It has been shown previously that the mechanical properties of PVA-C depend greatly on the number of FTCs. More work on mapping the mechanical, electrical, and MRI properties is needed before using PVA-C as human tissue phantoms.

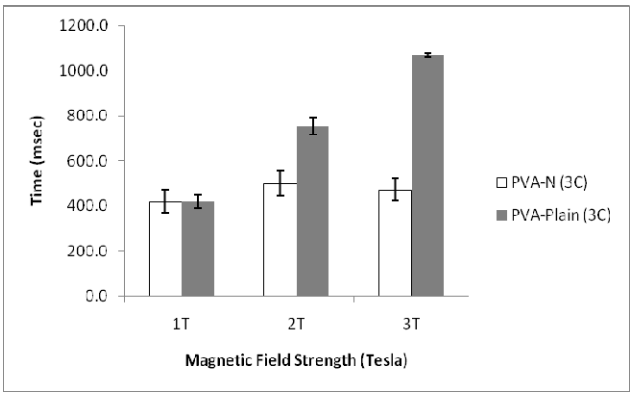

Figure 1 –T1 Relaxation Times for PVA at 1, 2 & 3T

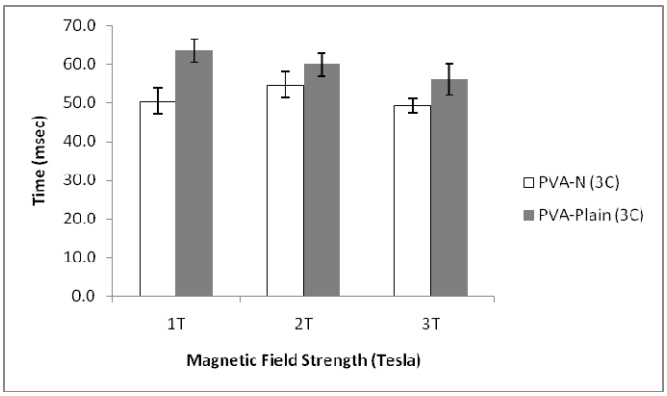

Figure 2 – T2 Relaxation Times for PVA at 1, 2 & 3T

1. C.M. Hassan, N.A. Peppas. Advances in Polym Sci, 153: 37-65, 2000.
2. N.F. Sheppard, et al. Sensors & Actuators B, 10(2): 73-77, 1993.
3. F. Yokoyama, et al. Colloid & Polymer Sci, 264: 595-601, 1986.
4. K.J.M. Surry, et al. Phys. Med. Biol., 49: 5529-5546, 2004.