Dependence of Concentration and Field Strength on MRI Properties of Polyvinyl Alcohol Cryogel

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Introduction

It is not always practical or ethical to use human subjects for optimization and testing of MR pulse sequences especially when dealing with neonates and children where T1's and T2's are substantially different from adults[1]. Thus, a tissue mimicking phantom would be useful. Polyvinyl Alcohol Cryogel (PVA-C) is a non- toxic material that has been shown to have MR relaxation characteristics similar to aorta, muscle and fat (350ms<T1<800ms, 30ms<T2<95ms) [2]. Chu et al measured T1 and T2 at 1.5 Tesla as a function of the number of Freeze Thaw Cycles, (FTCs) keeping the concentration of PVA constant at 15% (weight PVA/water). A greater range in relaxation values is required to mimic all tissues in the body. Fat has a T1 and T2 as short as 250 and 60ms, respectively, whereas in neonatal brain values of T1 as long as 2900 ms and T2 of 270ms have been reported [1]. We hypothesized that we could increase the range for T1 and T2 by varying the concentrations of PVA (3-30%) and using 1 FTC. To determine if there was a dependency on the magnetic field, the measurements were made at 1.89 & 3T.

Methods

The 3, 6, 10, 15, 17, 19, 25, 30% by weight of polyvinyl alcohol (molecular weight 146 000 – 186 000) powder were mixed with de-ionized water. The mixture was heated to 95^0C in 2 hours with use of a standard reflux column and flask combination. The resulting solution was then placed in molds in the shape of a mini-puck (24mm diameter x 21mm thick). The PVA samples then went through 1 freeze thaw cycle in a temperature controlled bath. One freeze thaw cycle consists of going from 20^0C to -20^0C back to 20^0C at a rate of 0.1^0C/min. The samples were then removed and stored in tap water.

Image based measurements of T1 & T2 were performed using custom built 1.89T, and 3T MR systems. T1 was measured using a 2D inversion recovery imaging sequence repeated with 30 different inversion times (TI), linearly spaced from 50 to 4500ms (TR=15sec, TE=16ms). T1 maps were created using pixel by pixel non-linear least square fit to the equation $S = K[1-2\exp(-TI/T1)]$ and a ROI drawn and the average T1 calculated with the variation across the ROI. T2 was measured using a spin echo imaging sequence repeated with 20 different echo times (TE), which were linearly spaced from 17 to 400ms (TR=6sec). T2 maps were created using pixel by pixel log-linear least square fit and a ROI drawn and the average T2 calculated with the variation across the ROI.

Results

Figures 1 and 2 show T1 and T2 values obtained at both field strengths. T1 and T2 for 2T and 3T measurements correlated nicely with an R^2=0.99, $p<0.01$ and R^2=0.99, $p<0.01$ respectively. The relaxation values exhibited a plateau in both T1 and T2 for concentrations greater than 17%. For T1 the plateau occurred at 735 +/- 49ms and 750 +/- 41ms for 2T and 3T respectively. For T2 the plateau occurred at 70 +/- 8ms and 63 +/- 11ms for 2T and 3T respectively.

Discussion

Changing the %PVA from 3-30% has extended the range for both T1 and T2 (700ms<T1<1860ms, 70ms<T2<460ms) over that available by changing the number of FTCs. Interestingly, it was previously shown that varying the number of FTCs above 6 also produced a plateau in T1 and T2 values in a 15% PVA [2] measured at 1.5T. Plateaus observed by Chu et al are 36 and 41% lower for T1 and T2, respectively, than what we observed. By varying both the %PVA and the number of FTCs it might be possible to mimic most of the range of relaxation values needed to mimic most tissue, but for the long T1 values sometimes found in neonatal brain, different preparations of the PVA-C will be required.

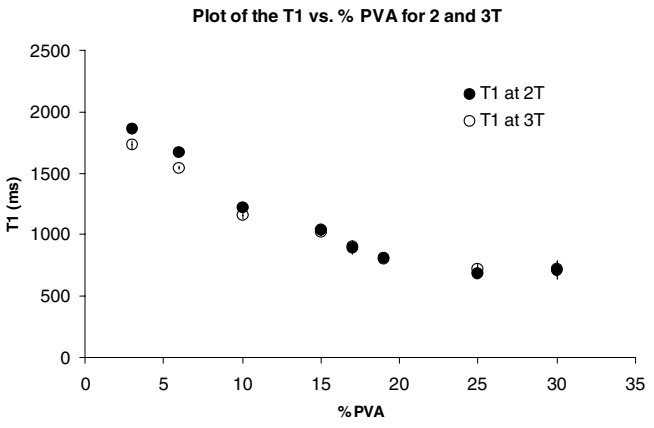

Figure 1 – T1 Relaxation Times for PVA-C at 2T and 3T

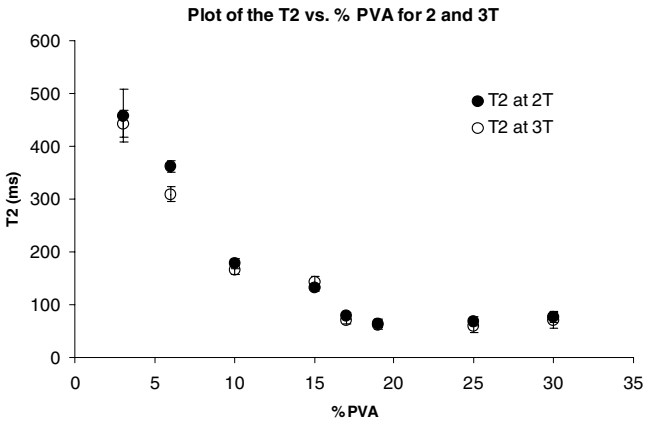

Figure 2 – T2 Relaxation Times for PVA-C at 2T and 3T

1. L. Williams et al., Radiology, 595-603, May 2005.
2. K. Chu, B. Rutt., Magn. Reson. in Med. 37:314-319(1997).