Supporting information:

**Figure S1:** Pulse sequence used for the measurement of low-field longitudinal relaxation of water protons on the sample shuttle apparatus. Narrow filled and wide open rectangles represent 90° and 180° pulses respectively. The recycle delay was 5 s, $\tau_{\text{up}}$ and $\tau_{\text{down}}$ were between 60 and 200 ms, depending on the low-field position. The stabilization delay $\tau_{\text{st}}$ was 250 ms. The phase cycle is $\varphi_1 = \{x, y\}$; $\varphi_2 = \{x, x, -x, -x, y, y, -y, -y\}$; and $\varphi_{\text{acq}} = \{x, -x, -x, x, y, -y, -y, y\}$. The inversion of proton polarization every other scan leads to a decay of measured intensities (or integrals) towards zero. The delays $T_{\text{rel}}$ were adapted to the relaxation rates at each low field. Ten different delays were chosen and two were repeated. The difference between the minimum and the maximum delays $T_{\text{rel}}$ varied between 250 ms and 3.5 s for the USPIO solution and between 0.8 and 1 s for the Gadospin™ solution.