NMR probes of red cell deformation

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The mean circulation time of a red blood cell (RBC) in an adult human is ~1 minute. Thus each RBC in passing through the peripheral and the pulmonary capillary beds undergoes deformation, from its biconcave-disc shape to an elongated bullet shape, and the reverse, every 30 seconds.

^{23}Na and ^{133}Cs nuclei have spin >1/2 and thus a nuclear electric quadrupole. This renders their NMR resonance frequency sensitive to the presence of electric field gradients at binding surfaces. Such gradients exist in anisotropic media.

Gelatine, which sets at temperatures below ~30°C, was cast inside a silicone rubber tube that in turn was placed inside a glass tube. Thus the gelatine could be stretched by a factor of up to ~2; in the process the gelatine developed structural anisotropy. This anisotropy was evident as a splitting into three of the $^{23}Na^{+}$ NMR resonance, whereas the $^{133}Cs^{+}$ NMR resonance was split into a septet. In both cases the residual quadrupolar coupling constant was a linear function of the extent of stretching.

RBCs set in the gelatine revealed separate resonances for $^{133}Cs^{+}$ inside and outside the cells. And, stretching the gelatine also stretched the RBCs as was apparent from the emergence of quadrupolar splitting of the intracellular $^{133}Cs^{+}$ resonance.

Finally, the metabolic activity of the RBCs was measured using ^{13}C NMR, with D-[U-^{13}C]glucose as substrate, when the cells were in the stretched or unstretched states.

These findings allow comment on the energy cost of the return of an RBC to its equilibrium shape, after distortion.