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Oxygen-17 Magnetic Resonance Imaging[1]

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Water is the primary signal source in Magnetic Resonance Imaging. So far, proton detection has been exclusively used because of its high sensitivity, while the O-17 nucleus has generally been cosidered impractical for MRI, owing to its "unfavorable" properties: very low natural abundance, low detection sensitivity, and considerable quadrupolar broadening.

We report the first ^{17}O imaging (OMRI) experiments and present evidence that some of the "drawbacks" mentioned above can be turned into advantages. In the absence of specialized equipment, our approach was essentially the same as in Lauterbur's historical "zeugmatograpy" endeavor.[2] The O-17 projection reconstruction of a T-shaped phantom shown in Figure 1 compares favorably with the proton image of a similar phantom described in a review by Andrew.[3] Although 1000 times less sensitive, the O-17 measurement in natural abundance takes only ~10 times longer than the proton measurement. This is due to its much faster (quadrupolar) relaxation which allows many more scans per unit time.

Furthermore, as seen in Figure 2, isotopic enrichment brings OMRI feasibility even closer to proton MRI. In this experiment, the sealed end of a glass capillary containing 1 microliter of ^{17}O-enriched water was inserted at the periphery of a chicken heart, immediately after excision. The broad projection in Figure 2a is due to the natural abundance ^{17}O signal from the entire heart while the intense, sharp signal (Figure 2b) originates from the minute volume of enriched H_2O contained in the capillary. It is thus possible to obtain strong contrast between "labelled" and "nonlabelled" regions. T_2 weighting should be quite effective. This suggests the feasibility of a large number of investigations of the kidney, heart, brain, blood vessels (including flow), etc. The O-17 enriched water or other compounds (glucose and other organic molecules, as well as oxyanions) would be bona fide contrast agents, as they would be, themselves, the image source.

Figure 2c shows the reconstruction of the image of two capillaries containing 1 microliter of ^{17}O enriched water, introduced, via catheters (located at the x signs in the heart sketch) through the dorsal aorta and the pulmonary arterial arch, into the corresponding ventricles.

Combining ^{17}O with ^{1}H ("tandem") imaging should add considerable subtlety to image interpretation; due to the vastly different magnetic resonance characteristics of the two nuclei,[1,4] new aspects are bound to be revealed.

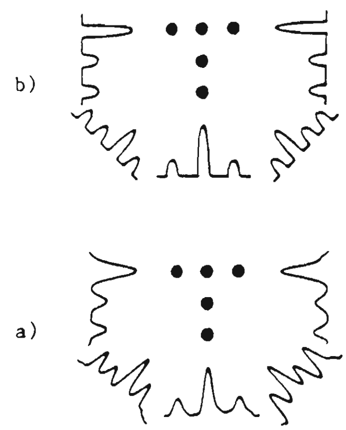

Figure 1. a) O-17 projections of 5 tubes containing natural abundance water (18000 pulses at .03 s intervals, 0.7 G/cm x-gradient). b) Proton projections (see Ref. 3)

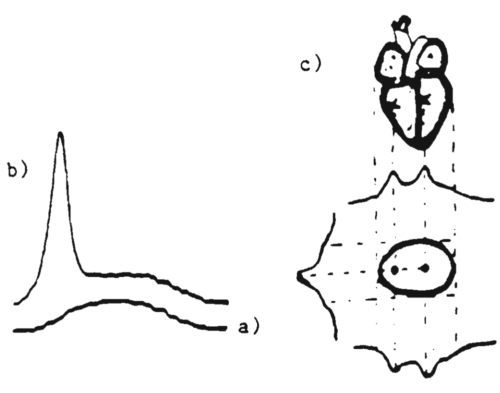

Figure 2. a) O-17 projection of natural abundance chicken heart. b) Same as above, but with 1 microliter 50% O-17 enriched H_2O capillary inserted in the external ventricular wall. c) See text. Each projection taken with 512 pulses at .06 s intervals.

References

1. Presented in part at the 9th ISMAR meeting, Rio de Janeiro, June 1986.
2. Lauterbur,P., Nature 242, 190, 1973.
3. Andrew, E.R., Accts. Chem. Res., 16, 114, 1983.
4. Mateescu,G., Benedikt,G., Kelly, M., "New Dimensions in O-17 NMR", in Synthesis and Applications of Labelled Compounds, Duncan & Susan, Eds., Elsevier: Amsterdam. 1983, 483.