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N.m.r. relaxation and images of human breast tumours *in vitro*

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[Plate 1]

It is found that fat and non-fatty tissue in dissected samples of the mamma differ in their T_1/T_2 ratios. This opens the possibility of locating tumours by n.m.r. imaging, because they have a lower fat content than their surroundings. By means of a sensitive point method, samples were scanned with a resolution of about 0.4 mm × 0.4 mm. The similarity between the shape of a tumour in an n.m.r. and in an X-ray image of a thin section of mamma tissue is quite convincing.

Introduction

Since the suggestion by Damadian that nuclear magnetic resonance (n.m.r.) can be used as a diagnostic tool for cancer (Damadian 1971) many authors have investigated relaxation times of cancerous and non-cancerous tissue (see, for example, Goldsmith *et al.* 1978 and the references cited there). In many instances Damadian's finding that cancerous tissue has a longer T_1 than non-cancerous tissue has been confirmed.

In 1973 Lauterbur introduced a new technique (Lauterbur 1973), zeugmatography or spin imaging, which makes possible the determination of, for example, the spatial distribution of T_1 values in a given object and hence, in view of Damadian's findings, the location of a malignant tumour in a body.

We have concentrated on investigating relaxation times of human mamma tissue *in vitro* and on making spin images of thin sections of this tissue.

Relaxation times

In the adult female breast, connective tissue (ligamenta suspensoria mammae) and glandular tissue with supporting connective tissue are normally heavily admixed with fat. Therefore, one can expect that the spin–lattice relaxation is not single exponential. Indeed, it is found that two time constants are needed to describe the experimental spin–lattice relaxation curve: one corresponding to the fat (T_{1s} of about 200 ms) and one corresponding to the non-fatty tissue (T_{1l} of about 900 ms). Histograms of T_{1l} values (Bovée *et al.* 1978) of malignant and non-malignant mamma tissues show a considerable overlap. Moreover, there is no significant difference between the mean values of T_{1l} in malignant and in non-malignant tissues.

In the spin imaging method that we used, the spin–spin relaxation time, T_2, also plays a role. Because the decay of the transverse magnetization, measured by means of the CPMG method, proved to be non-exponential even in the case of pure fat and fatless tissue, we defined T_2 as a weighted average of the shortest and the longest time constants involved. Because of the problem in analysis of the transverse decay curves, we hesitate at this moment to make a statement about possible differences in T_2 between malignant and non-malignant tissue.

The mean values of the relaxation times measured at a frequency of 60 MHz and their ratio are given in table 1.

TABLE 1. T_1 AND T_2 DATA OF MAMMA TISSUE (frequency, 60 MHz)

	non-fatty tissue	fat
mean value of T_{1l}	900 ms	—
mean value of T_{1s}	—	200 ms
mean value of T_2	45 ms	100 ms
T_1/T_2	20	2

N.M.R. IMAGES

N.m.r. images of thin sections (20 mm × 20 mm × 2 mm) of mamma tissue were obtained at 24 MHz by the sensitive point method (Hinshaw 1974, 1976).

With Hinshaw's method, the intensity of the signal obtained is proportional to $(1 + T_1/T_2)^{-1}$, with the assumption that the sample has a uniform proton density. On the basis of the data in table 1 it can be expected that in the n.m.r. images of mamma tissue there will be a good contrast between fat and non-fatty tissue. So a tumour, which has a lower fat content than its surroundings, can be made visible, as demonstrated in figure 1*a*. Figure 1*b* shows an X-ray image of the same slice of tissue. There is a convincing similarity between the shape of the tumour in the n.m.r. image and that in the X-ray image.

At this moment we are not able to see if the tumour is benign or malignant. However, it is possible that spin images *in vivo* will show a difference between benign and malignant tumours due to a difference in shape and/or in the T_1/T_2 ratio.

REFERENCES (Bovée *et al.*)

Bovée, W. M. M. J., Getreuer, K. W., Smidt, J. & Lindeman, J. 1978 *J. natn. Cancer Inst.* **61**, 53–55.
Damadian, R. 1971 *Science, N.Y.* **171**, 1151–1153.
Goldsmith, M., Koutcher, J. A. & Damadian, R. 1978 *Br. J. Cancer* **38**, 547–554.
Hinshaw, W. S. 1974 *Phys. Lett.* A **48**, 87–88.
Hinshaw, W. S. 1976 *J. appl. Phys.* **47**, 3709–3271.
Lauterbur, P. C. 1973 *Nature, Lond.* **242**, 190–191.

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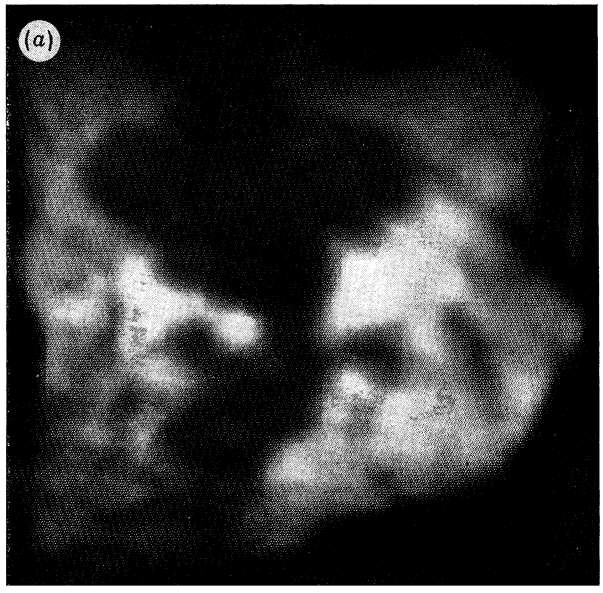

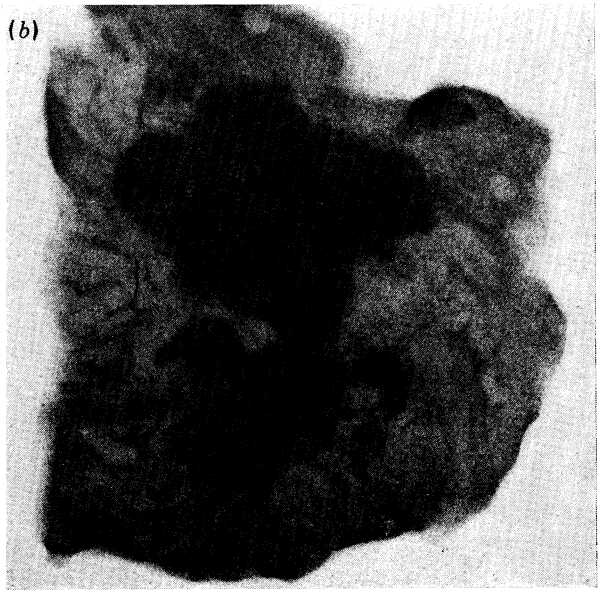

20 mm

FIGURE 1. (*a*) An n.m.r. of a 2 mm thin section of breast tissue through the body of a malignant tumour. The tumour is dark in a bright background of fat. The resolution is about 0.4 mm × 0.4 mm. (*b*) An X-ray image of the same section.

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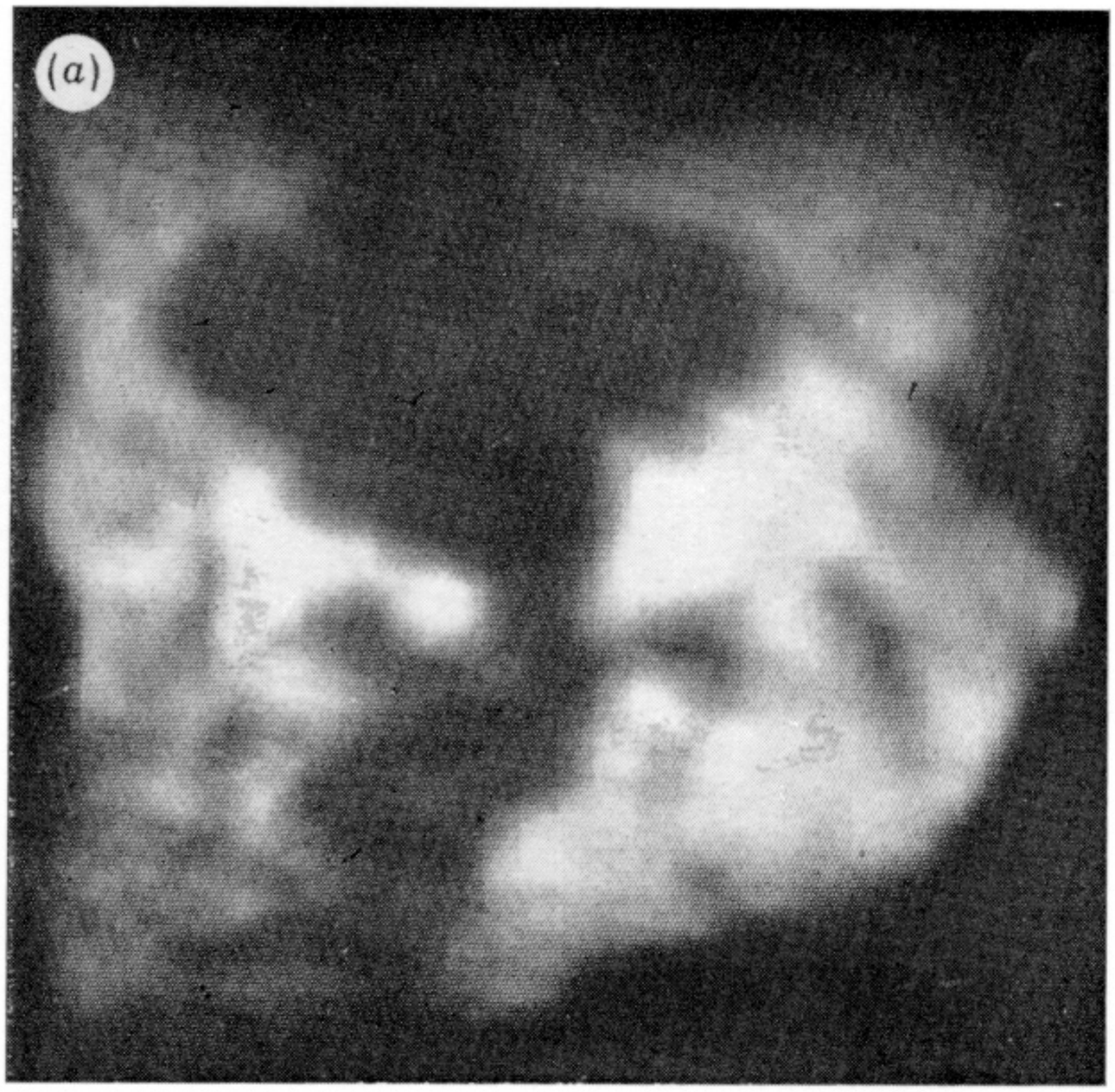

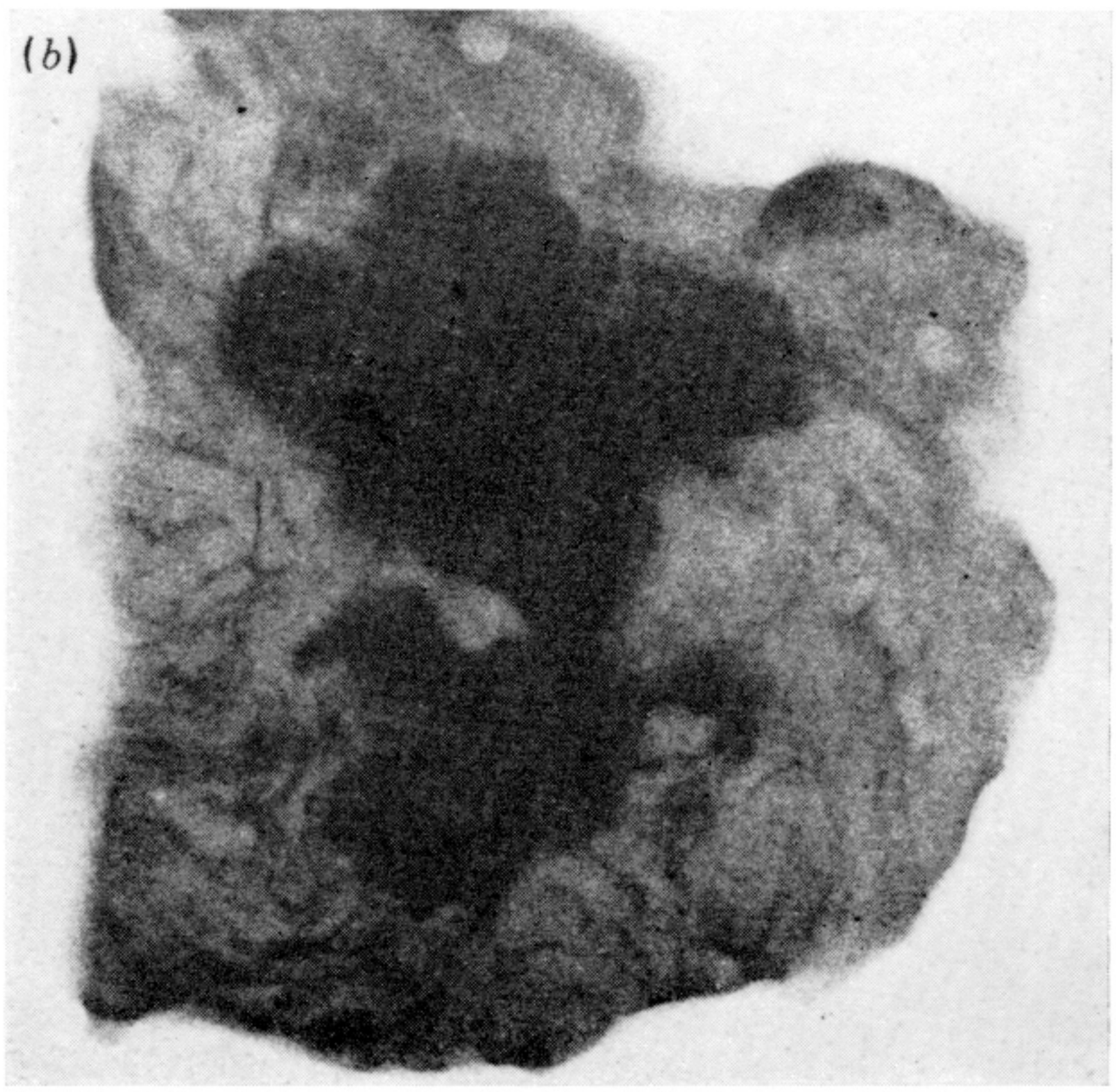

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