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Intracranial Hematomas Studied by MR Imaging at 0.17 and 0.02 T

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Abstract: The contrast in magnetic resonance (MR) images relies mainly on the relaxation time differences between the tissues. The relative differences in relaxation times T1 are bigger at lower field strengths, although the absolute values of T1 are smaller. A shorter T1 is also advantageous for the contrast of the T2 and proton density weighted images because of the more complete recovery of the spin system during the repetition time TR. Scrutiny of the clinical results of MR shows some unsolved problems in the specificity of diagnosing fresh intracranial hematomas. Low field MR imaging at 0.02 T seems to offer new vistas in this sense. Fresh subdural hematoma was more easily detected and differentiated at 0.02 T than at 0.17 T. The T2 of fresh intracranial hematomas was rather short compared with cerebrospinal fluid and edema and, unlike T1, was not highly dependent on magnetic field strength. The different visualization of acute versus late intracerebral hematoma and the changes during the resorption were demonstrated in follow-up studies of two patients at 0.17 T and of one at 0.02 T. In one patient the same lesion was imaged successively at both field strengths, showing the divergent contrast in the inversion recovery images at 0.02 and 0.17 T. **Index Terms:** Hematoma, cerebral—Hematoma, subdural—Brain, hemorrhage—Nuclear magnetic resonance.

The magnetic resonance (MR) imaging process is affected by a multitude of user-selectable parameters. The signal-to-noise (S/N) ratio and hence the resolution are dependent on the polarizing magnetic field strength (1). The relaxation times, especially T1, also depend on the field strength (2–5). The contrast in MR images is due to the combined weighting of the tissue parameters (proton density, motion, T1, T2) and is thus dependent on the interpulse delays of the imaging sequence selected (6–9).

In this report we deal with the problems arising in the detection and differential diagnosis of intracerebral (ICH) and subdural hematomas (SDH) at field strengths above 0.15 T (10–12). The potential of low field imaging is explored by reporting our preliminary results with ICH and SDH imaged at 0.02 T. Comparison is made with the results obtained at 0.17 T. Some findings from the follow-up studies, which elucidate the possible changes occurring during resorption of the hematomas, are also reported.

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MATERIALS AND METHODS

The two developmental imagers operate at magnetic field strengths of 0.17 and 0.02 T. The corresponding proton resonance frequencies are 7.13 and 0.8 MHz (Instrumentarium Corporation, Helsinki, Finland). The 0.17 T magnetic field strength is produced by a superconducting magnet and the 0.02 T by a resistive electromagnet.

The experiments are briefly characterized as follows. Two-dimensional Fourier transformation was used as the imaging method for both devices. The data acquisition was carried out by spin echo (SE). The selective excitation method was used to define a slice approximately 1 cm thick at 0.17 T and 1.5 cm at 0.02 T. The imaging matrix was 128 × 128 at 0.17 T and 128 × 256 at 0.02 T. Two pulse sequences were used and are presented in Table 1. The inversion recovery (IR) sequence is T1 weighted and the SE sequence with a long repetition time and long echo time (TE) is T2 weighted.

TABLE 1. *Pulse sequences and time variables used*

	0.17 T			0.02 T		
	TR (ms)	TE (ms)	TI (ms)	TR (ms)	TE (ms)	TI (ms)
IR	1,500	30	400	1,000	70	200
SE	2,000	160		2,000	160	

In one patient a TI of 250 was used due to the long T1 of the lesion (Fig. 9b).
IR, inversion recovery; SE, spin echo; TE, echo time; TI, inversion time; TR, repetition time.

Noncontrast X-ray CT was available for comparison. The study protocol was approved by the Ethical Committee of the Helsinki University Central Hospital.

RESULTS

Imaging at 0.17 T

Figure 1 shows an ICH on noncontrast CT and SE 2,000/160 images 2 and 8 days after the acute onset of the symptoms. At 2 days the lesion was hyperdense on CT and was visualized as dark with a bright surrounding rim in the SE image. At 8 days the CT showed partial resorption of the hemorrhage (Fig. 1c) and the SE image revealed a bright intensity in the center of the lesion (Fig. 1d). Thus the T2 weighted images showed a major change in the visualization of the lesion during resorption. A change with aging of ICH was also demonstrated in the T1 weighted IR 1,500(400)/30 images (Fig. 2). A 5-day-old ICH was imaged by CT (Fig. 2a) and by MR with IR sequence (Fig. 2b). The same section was reimaged at 18 days using the same IR sequence. A bright intensity focus (Fig. 2c) had replaced the dark area present in the previous examination.

Acute (Fig. 3) and chronic (Fig. 4) SDH are presented in noncontrast CT and with the IR images. In both patients a midline shift was detected. The acute hematoma was hyperdense on CT (Fig. 3a) and was faintly discernible in the IR image. At autopsy a fresh SDH was found. The chronic hematoma exhibited both hypodense and hyperdense parts on CT (Fig. 4a) and was clearly demonstrated in the IR image (Fig. 4b). The chronic hematoma was confirmed at operation. Thus SDH were visualized differently with the same pulse sequence at 0.17 T, indicating that the lesions have different relaxation times.

Imaging at Both 0.17 and 0.02 T

One patient with a 10-day-old ICH was imaged on noncontrast CT and with the IR sequences at both field strengths. Computed tomography (Fig. 5a) showed a thalamic ICH, which was also demonstrated at 0.17 T in the IR 1,500(400)/30 image (Fig. 5b), having a grayish center with a bright surrounding rim. The lesion was visualized differently in the IR 1,000(200)/70 image at 0.02 T (Fig. 5c). In this image the center of the lesion showed a bright intensity.

1a–d

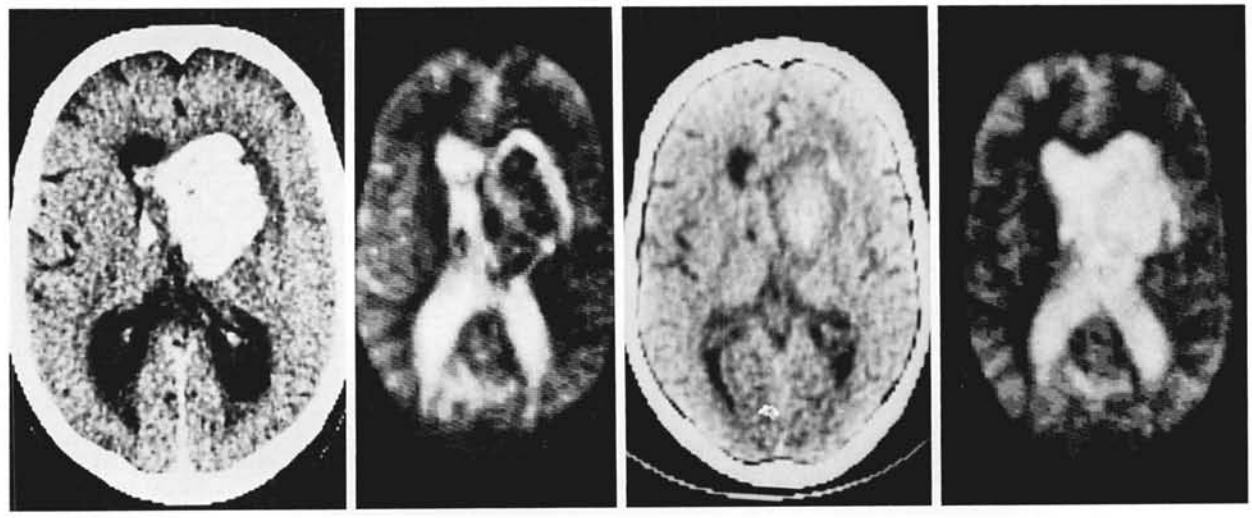

FIG. 1. Intracerebral hematoma imaged 2 days after the onset of symptoms on noncontrast CT scan **(a)** and at 0.17 T with the spin echo 2,000/160 sequence **(b)**. The same section was reimaged at 8 days **(c and d)**.

2a–c

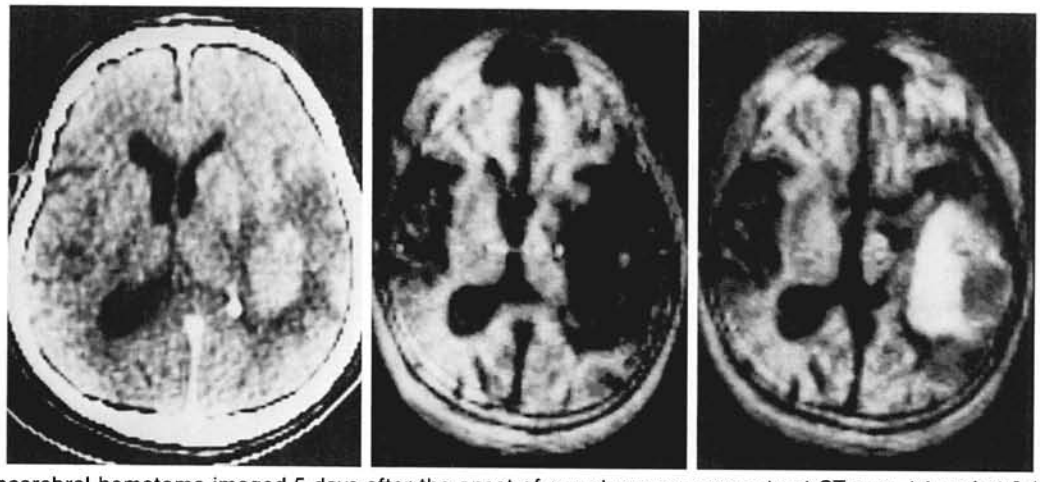

FIG. 2. Intracerebral hematoma imaged 5 days after the onset of symptoms on noncontrast CT scan **(a)** and at 0.17 T with the inversion recovery (IR) 1,500(400)/30 sequence **(b)**. The same section was reimaged at 18 days with the IR sequence **(c)**.

Imaging at 0.02 T

Figure 6 shows an ICH 8 h after the acute onset of the symptoms in CT (Fig. 6a), IR 1,000(200)/70 (Fig. 6b), and SE 2,000/160 (Fig. 6c) images. The IR image shows a bright intensity and the SE image an intensity of about that of the brain tissue in the center of the lesion. A bright zone encircles the lesion in the SE image. The patient was reimaged 2 months later with the IR and SE sequences. The center of the lesion showed low intensity with a faint surrounding rim in the IR image (Fig. 6d). In the SE image a bright intensity was revealed in the center of the lesion (Fig. 6e). Both the T1 and T2 weighted images showed major changes from the acute stage.

In Figures 7–9 both acute and chronic SDH and a patient with hygroma are presented in noncontrast CT, IR, and SE images. The acute SDH was hyperdense on CT (Fig. 7a) and showed a high intensity in the IR image (Fig. 7b) but a medium intensity in the SE image (Fig. 7c). The chronic SDH was hypodense in CT (Fig. 8a) and showed up faintly in the IR image (Fig. 8b) but was clearly demonstrated in the SE 2,000/160 image (Fig. 8c). A hygroma cannot be differentiated from a chronic SDH with CT (Figs. 8a and 9a). On the other hand, the visualization of a hygroma in the IR 1,000(250)/70 (Fig. 9b) and SE (Fig. 9c) images is different from that of the SDH.

DISCUSSION

Contrast in MR images is a function of a number of parameters that are dependent on the imaging device. The importance of the interpulse time parameters is well recognized and their effects on the

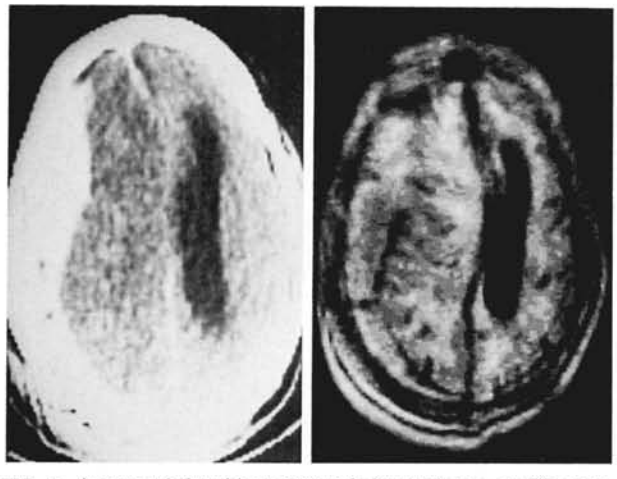

FIG. 3. Acute subdural hematoma is hyperdense on CT scan **(a)** and faintly discernible in the inversion recovery 1,500(400)/30 image at 0.17 T **(b)**.

4a,b

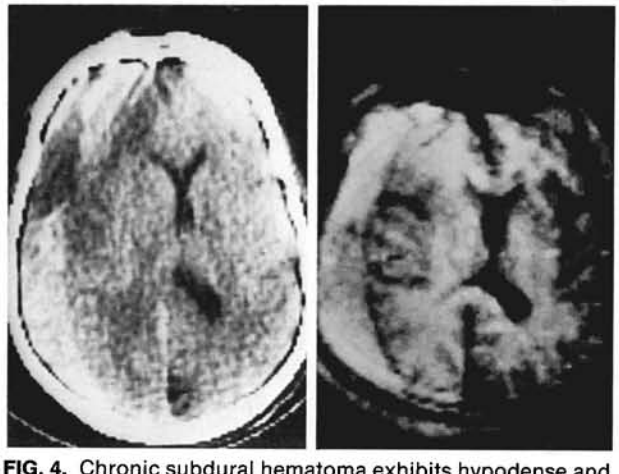

FIG. 4. Chronic subdural hematoma exhibits hypodense and hyperdense areas on noncontrast CT scan **(a)** and is clearly visualized in the inversion recovery 1,500(400)/30 image at 0.17 T **(b)**.

5a–c

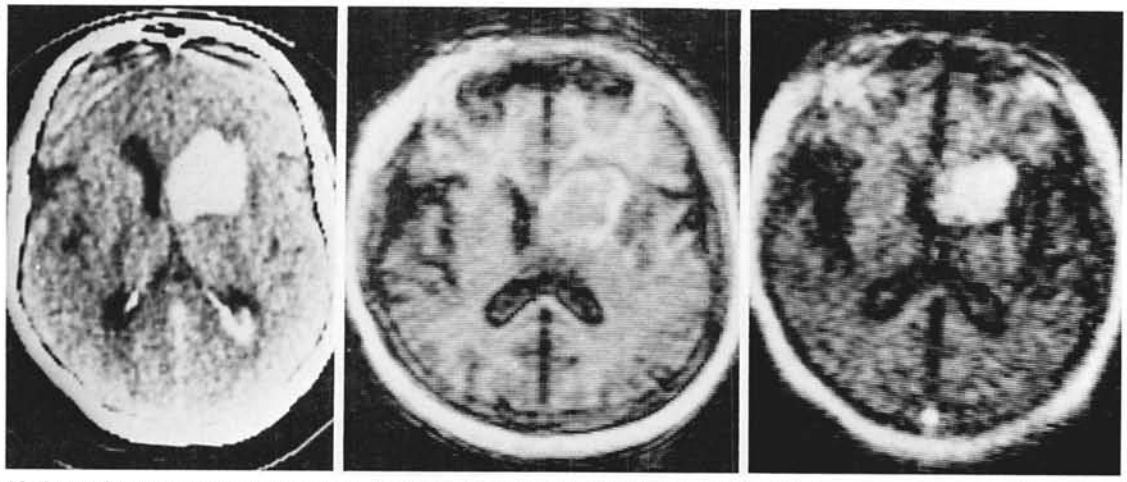

FIG. 5. A 10-day-old intracerebral hematoma is shown on noncontrast CT scan **(a),** with inversion recovery (IR) 1,500(400)/30 at 0.17 T **(b)** and with IR 1,000(200)/70 at 0.02 T **(c).** The difference in visualization of the same lesion in the T1 weighted images at 0.17 and 0.02 T is demonstrated.

6a–c

6d,e

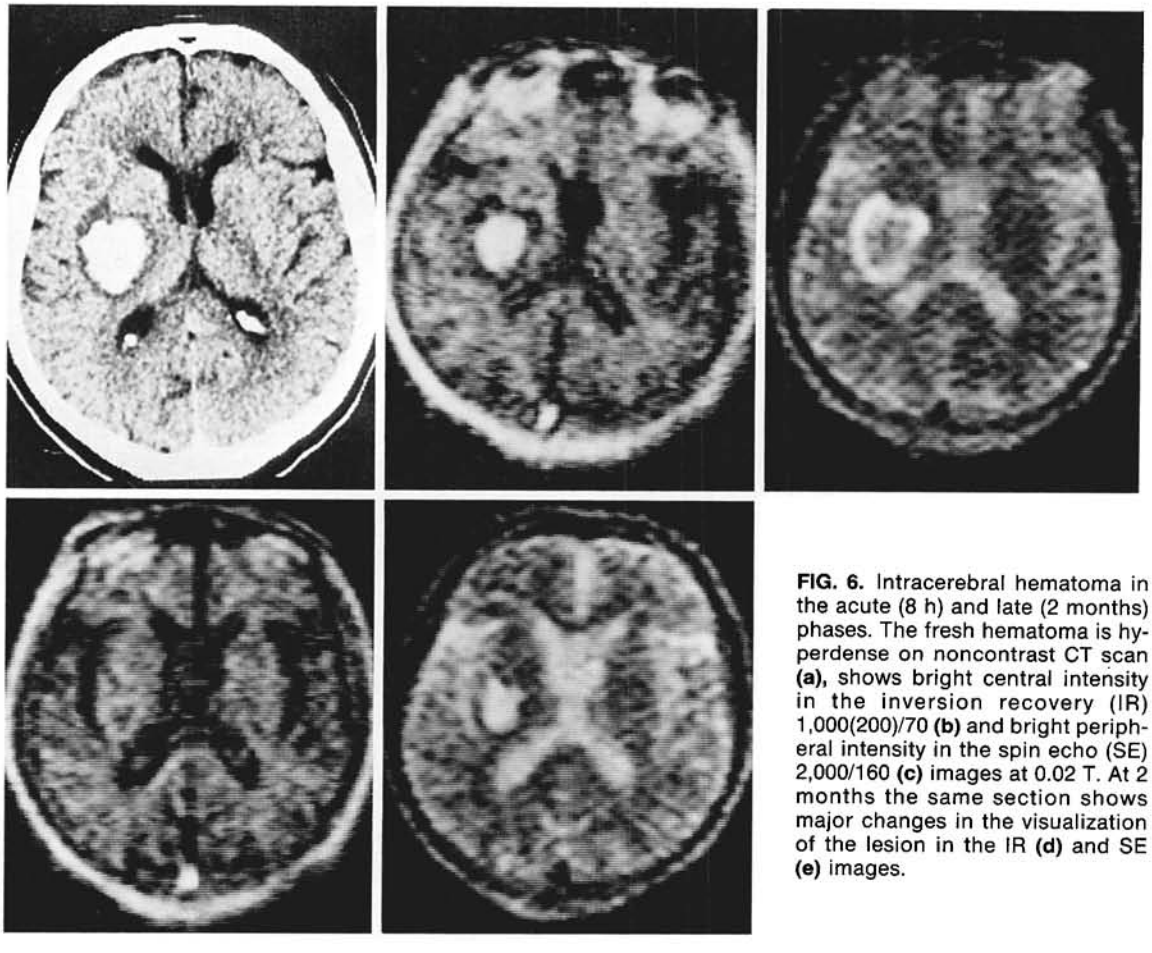

FIG. 6. Intracerebral hematoma in the acute (8 h) and late (2 months) phases. The fresh hematoma is hyperdense on noncontrast CT scan **(a),** shows bright central intensity in the inversion recovery (IR) 1,000(200)/70 **(b)** and bright peripheral intensity in the spin echo (SE) 2,000/160 **(c)** images at 0.02 T. At 2 months the same section shows major changes in the visualization of the lesion in the IR **(d)** and SE **(e)** images.

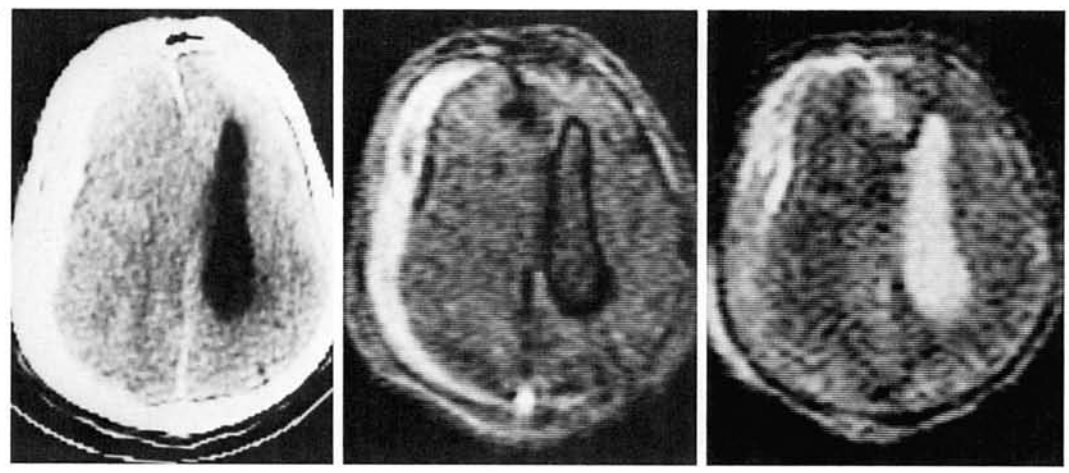

FIG. 7. Acute subdural hematoma is hyperdense on CT scan **(a)**, is clearly discernible in inversion recovery 1,000(200)/70 image **(b)**, and shows a medium intensity in the spin echo 2,000/160 image **(c)** at 0.02 T.

image contrast have been widely explored (6–9). Magnetic resonance devices currently operate mainly above 0.1 T but clinical results at 0.04 T have been reported by Hutchison et al. (13). The effects of the field strength above 0.15 T have been discussed (14) but the lower field range has not been surveyed in comparative studies. Theoretical calculations indicate that, despite the smaller relative T1 differences, the better S/N ratio at higher field strengths will improve the image contrast (15). However, in practice an increase in polarizing magnetic field strength also increases the absolute inhomogeneities of the field and the effect of the chemical shift artifact (16). Compensation can be obtained by using stronger field gradients and a larger signal bandwith. This reduces the gain achieved by increasing the magnetic field strength. Finally, the effect of the field strength on the diagnostic efficiency must be tested in clinical practice.

The detection and differentiation of intracranial hematomas with MR imaging, especially in the acute phase, has been found to cause problems at field strengths above 0.15 T (10–12). The lack of contrast is due to the similarity between the MR parameters of fresh hematomas and those of the surrounding brain tissue. In this comparative study we have reported results in the visualization of intracranial hematomas imaged at 0.17 and 0.02 T. Both field strengths are currently classified in the low field range. However, there is a large difference between these field strengths. Notable differences between the relaxation times T1 of biological tissues at these field strengths have been reported in earlier spectroscopic studies (2,5,17,18) and thus an impact on the T1 dependent image contrast was to be expected.

At 0.17 T the fresh SDH appeared much like the adjacent brain tissue in the IR 1,500(400)/30 image,

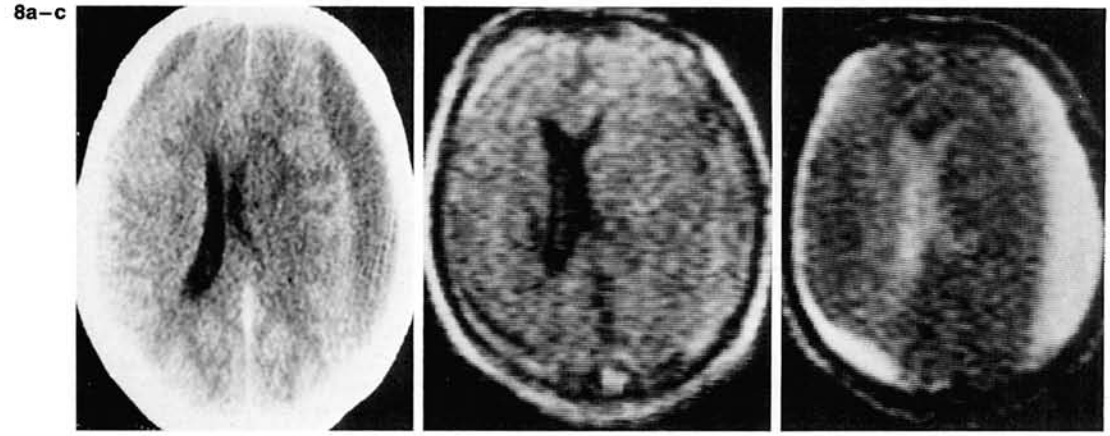

FIG. 8. Chronic subdural hematoma is hypodense on noncontrast CT scan **(a)**, is faintly visualized in the inversion recovery 1,000(200)/70 image **(b)**, but is clearly discernible in the spin echo 2,000/160 image **(c)** at 0.02 T.

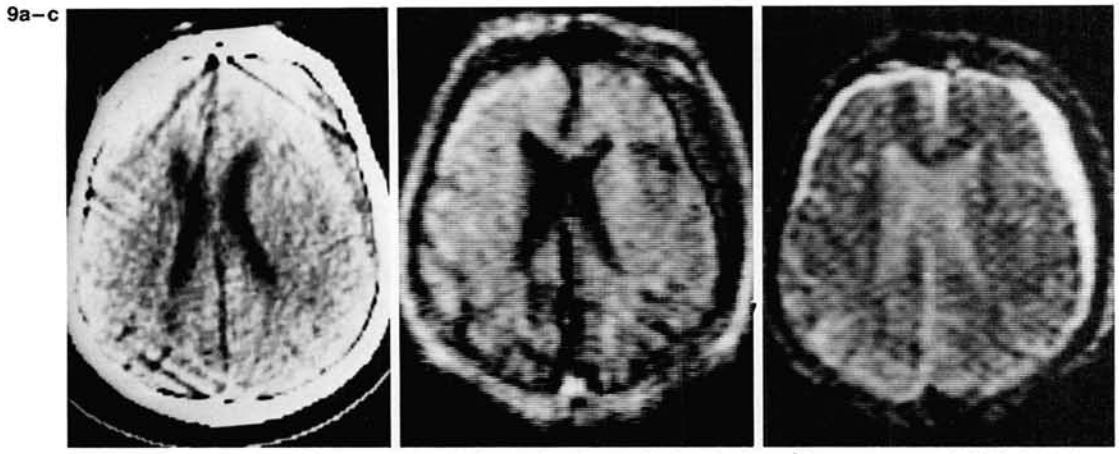

FIG. 9. A hygroma is hypodense on CT scan **(a)** and shows low intensity in the inversion recovery 1,000(250)/70 image **(b)** due to the relatively long T1 of the lesion. This permits differentiation from subdural hematoma. In the T2 weighted spin echo 2,000/160 image **(c)** the lesion is visualized as bright due to the long T2.

indicating about equal relaxation times T1 (Fig. 3b). At 0.02 T the acute SDH was visualized as bright in the IR 1,000(200)/70 image, indicating a shorter relaxation time T1 than that of the adjacent brain tissue (Fig. 7b). In the T2 weighted SE 2,000/160 image the lesion is only slightly brighter than the brain tissue, indicating a somewhat longer relaxation time T2. However, the intensity of the lesion is clearly below that of cerebrospinal fluid.

A marked difference was also observed in the visualization of acute ICH at different field strengths, as clearly shown in Fig. 5. In the IR image at 0.17 T (Fig. 5b) the center of the lesion is shown as an area of intensity equal to that of the brain tissue and is encircled by a bright zone. On the other hand, in the IR image at 0.02 T the center of the lesion is bright and is encircled by a dark zone. Thus the relaxation time T1 of the lesion is shorter than that of the brain tissue at 0.02 T. Unlike the contrast in the T1 weighted IR images, the T2 weighted SE images demonstrated similar relaxation time differences at both field strengths. The relaxation time T2 of a fresh hematoma is comparable with that of the adjacent brain tissue (Figs. 1b an 6c).

In conclusion, the 0.02 T field strength seems to be advantageous in the visualization of fresh intracranial hematomas. The bright intensity of the lesion in the IR images at 0.02 T will differentiate fresh intracranial blood from other lesions, including brain infarctions and most neoplastic growths (19). The same type of differentiation seems to be somewhat more difficult at higher field strengths.

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