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Diagnostic value of the fast-FLAIR sequence in MR imaging of intracranial tumors

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Abstract. The aim of this study was to quantify imaging characteristics of fast fluid-attenuated inversion recovery (FLAIR) sequence in brain tumors compared with T1-postcontrast- and T2-sequences. Fast-FLAIR-, T2 fast spin echo (FSE)-, and T1 SE postcontrast images of 74 patients with intracranial neoplasms were analyzed. Four neuroradiologists rated signal intensity and inhomogeneity of the tumor, rendering of cystic parts, demarcation of the tumor vs brain, of the tumor vs edema and of brain vs edema, as well as the presence of motion and of other artifacts. Data analysis was performed for histologically proven astrocytomas, glioblastomas, and meningiomas, for tumors with poor contrast enhancement, and for all patients pooled. Only for tumors with poor contrast enhancement ($n = 12$) did fast FLAIR provide additional information about the lesion. In these cases, signal intensity, demarcation of the tumor vs brain, and differentiation of the tumor vs edema were best using fast FLAIR. In all cases, rendering of the tumor's inner structure was poor. For all other tumor types, fast FLAIR did not give clinically relevant information, the only exception being a better demarcation of the edema from brain tissue. Artifacts rarely interfered with evaluation of fast-FLAIR images. Thus, fast FLAIR cannot replace T2-weighted series. It provides additional information only in tumors with poor contrast enhancement. It is helpful for defining the exact extent of the edema of any tumor but gives little information about their inner structure.

Key words: MR imaging – Brain tumors – Comparative study – Fast-FLAIR imaging

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Introduction

T2-weighted sequences are well established in MRI of brain tumors. However, differentiation of the tumor from edema may be difficult if the tumor appears markedly hyperintense. To overcome those limitations, fluid-attenuated inversion recovery sequences (FLAIR) have been developed [1]. This heavily T2-weighted technique selectively suppresses the high signal of water, e. g., cerebrospinal fluid (CSF), so that hyperintense lesions, especially multiple sclerosis (MS) plaques, can be delineated more easily. Hajnal et al. [1] noted that those sequences can be useful for detecting brain lesions. In other studies FLAIR sequences were found to be useful in various conditions such as subarachnoid hemorrhage [2, 3], vascular disease [4, 5, 6], carbon monoxide poisoning [7], tuberous sclerosis [8], hippocampal sclerosis including palsy [9, 10], and herpes encephalitis [11].

Despite a shortened examination time (fast FLAIR: 3.5 min; echo-planar imaging 1.5 min) and the potential usefulness of FLAIR in brain tumors [4, 6], only one study exclusively dedicated to fast-FLAIR imaging in intracranial neoplasms has been reported [13]. Therefore, the following study was undertaken to evaluate the diagnostic value of fast FLAIR in comparison with a fast-spin-echo (FSE) T2- and a spin-echo (SE) T1-postcontrast sequence for different types of brain tumors.

Methods

The study group consisted of 74 patients (36 males and 38 females; mean age 49 years, age range 4–84 years; see Table 1) with intracranial tumors. The following MRI sequences were included in the study: (a) axial fast-FLAIR sequence (TR = 11,002 ms, TE = 132 ms, TI = 2600 ms, 256 × 192 pixels, 1 excitation, 1 acquisition, 19 slices with 5-mm thickness, 3 h 29 min scan time); (b) axial T2-weighted FSE images (TR = 3900–5000 ms, TE = 90–110 ms); and (c) T1-weighted SE images (TR = 500–600 ms, TE = 15 ms) after intra-

Table 1. MRI diagnoses of the patients and postoperative histological results

Tumor type	*N* (histologically confirmed)
Astrocytoma	23 (17)
Glioblastoma	14 (13)
Meningioma	13 (10)
Metastasis	5 (3)
Pituitary adenoma and prolactinoma	6 (3)
Acoustic schwannoma	2 (0)
Lymphoma	2 (2)
Others	9 (2)
Total	74 (50)

venous application of contrast medium (0.2 ml/kg; Magnevist, Schering, Berlin, Germany). Imaging was performed on a 1.5-T Signa system (General Electric Medical Systems, Milwaukee, Wis.). Histological proof was available in 50 patients. In the remaining cases, diagnosis was established clinically including the MRI aspects of the lesions.

All films were divided into three subgroups each containing only one series per patient. The films were presented to four neuroradiologists in three reading sessions in different random orders with a time interval of 1 week at least resulting in 4×74 (= 296) observations per sequence. All observers were blinded to the diagnosis. To assess the diagnostic value of the three sequences the observers were asked to subjectively assess the following nine criteria on a five- to six-point scale (definitions of the different scores in parentheses):

1. Signal intensity (SI) of the tumor compared with the SI of gray matter in that series (0 = tumor missed; 1 = SI comparable to the T1 signal of water; 2 = hypointense to gray matter but brighter than the T1 signal of water; 3 = isointense to gray matter; 4 = hyperintense to gray matter but not as bright as fat tissue; 5 = as hyperintense as fat tissue)
2. Inhomogeneity of the solid parts of the tumor (0 = tumor missed; 1 = more than 75 % of the tumor presenting the same SI; 2 = 50–75 % of the tumor presenting the same SI; 3 = 25–50 % of the tumor presenting the same SI; 4 = less 25 % of the tumor presenting the same SI)
3. Visualization of cysts within the tumor (0 = tumor missed; 1 = no cysts; 2 = cysts ≤ 25 % of the tumor; 3 = cysts 25–50 % of the tumor; 4 = cysts 50–75 % of the tumor; 5 = cysts ≥ 75 % of the tumor)
4. Differentiation of tumor vs normal brain tissue (0 = tumor missed; 1 = no differentiation between tumor and adjacent brain possible; 2 = 0–25 % of the tumor's contour differentiable from brain tissue; 3 = 25–50 % of the tumor's contour differentiable from brain tissue; 4 = 25–75 % of the tumor's contour differentiable from brain tissue; 5 = > 75 % of the tumor's contour differentiable from brain tissue)
5. Differentiation of tumor vs edema (definitions same as in item 4)
6. Differentiation of brain vs edema (definitions same as in item 4)
7. Intensity of contrast enhancement in the T1 series only (0 = none; 1 = minimal; 2 = poor; 3 = moderate; 4 = good; 5 = pronounced)

The following two types of artifacts were also scored:

1. Motion artifacts (1 = not present; 2 = present but not compromising image evaluation; 3 = compromising but not disabling image evaluation in areas without tumor or edema; 4 = compromising but not disabling image evaluation in the region of the tumor or the edema; 5 = evaluation of the tumor or the edema impossible)
2. All other artifacts including especially CSF flow phenomena, pulsations, and susceptibility artifacts

In patients with multiple tumors ($n = 3$), the greatest lesion had to be scored.

The data were averaged across the four readers. Data analysis was performed for the following more frequently occurring and histologically proven tumor types: astrocytoma ($n = 17$); glioblastoma ($n = 13$); and meningioma ($n = 10$). In the same way, those tumors that had shown an at most "moderate signal enhancement" (score ≤ 3 for every reader) after administration of contrast agent were analyzed as a separate group ($n = 12$). In order to allow for a comparison with the results of Tsuchiya et al. [13], also pooled data of all patients were analyzed. Student's paired *t*-test was used to determine the significance of the differences between the sequences.

Since the comparison of values pooled for all patients does not allow for establishing a direct ranking of the sequences in individual cases, the scores were separately compared with each other pairwise for each patient, reader, and criterion (for each criterion: $score_{fast\ FLAIR}$-$score_{T1}$; $score_{fast\ FLAIR}$-$score_{T2}$; $score_{T2}$-$score_{T1}$). The number of observations with higher ($score_{sequenceA} > score_{sequenceB}$), equal ($score_{sequenceA} = score_{sequenceB}$), and lower scores ($score_{sequenceA} < score_{sequenceB}$) were expressed in percentage of the total amount of observations per criterion and per analyzed group (astrocytomas: 17 patients × 4 reviewers = 68 observations; poor contrast enhancement: $12 \times 4 = 48$ observations; glioblastomas: $13 \times 4 = 52$ observations; meningiomas: $10 \times 4 = 40$ observations; total study group: $74 \times 4 = 296$ observations).

Results

Astrocytomas

With regard to astrocytomas (Table 2), the average SI score of these tumors was highest on fast FLAIR (average score 4.47). Direct ranking of the sequences showed a lower SI of the tumor on fast FLAIR than on T2-series in 11.8 % and a higher ranking of T1 than fast FLAIR in 23.5 %.

The average score for the demarcation of the tumor from brain and of brain from edema was superior with fast FLAIR. However, only in 33.8 % of the observa-

Table 2. Results for the astrocytoma group (68 observations per series). Average scores for all items and percentages found in the direct ranking of the scores of fast FLAIR vs T1 and fast FLAIR vs T2

	SI	Differentiation Tumor – Brain	Differentiation Tumor – Edema	Differentiation Brain – Edema	Inhomogeneity	Cysts	Motion artifacts	Other artifacts
Average score T1	4.18	3.93	3.07	2.37	2.92[e]	2.25[e]	1.79	1.74
Average score T2	4.21[a]	3.79	2.55	3.71[a]	2.61[b]	2.32[e]	1.54[b]	1.66[d]
Average score fast FLAIR	4.47	4.03	2.68	4.17	2.38	1.63	1.87	1.88
$Score_{fast\ FLAIR} > score_{T1}$ (%)	33.8	33.8	42.6	73.5	14.7	20.6	33.8	32.4
$Score_{fast\ FLAIR} = score_{T1}$ (%)	42.6	30.9	20.6	17.6	41.2	29.4	45.6	51.2
$Score_{fast\ FLAIR} > score_{T2}$ (%)	38.2	36.8	41.2	54.4	19.1	5.9	32.4	26.5
$Score_{fast\ FLAIR} = score_{T2}$ (%)	50.0	45.6	25.0	23.5	45.6	44.1	52.9	66.2

[a]Fast FLAIR significantly superior to this series at $P = 0.01$ level
[b]Fast FLAIR significantly inferior to this series at $P = 0.05$ level
[c]Fast FLAIR significantly superior to this series at $P = 0.001$ level
[d]Fast FLAIR significantly inferior to this series at $P = 0.01$ level
[e]Fast FLAIR significantly inferior to this series at $P = 0.001$ level

Table 3. Results for the low-contrast-enhancement group (48 observations per series). Average scores for all items and percentages found in the direct ranking of the scores of fast FLAIR vs T1 and fast FLAIR vs T2

	SI	Differentiation Tumor – Brain	Differentiation Tumor – Edema	Differentiation Brain – Edema	Inhomogeneity	Cysts	Motion artifacts	Other artifacts
Average score T1	2.78[a]	2.33[a]	1.82[a]	2.00[a]	2.53	2.06[b]	1.42[c]	2.13
Average score T2	3.95	3.43[d]	2.38	3.45[e]	2.40	1.91	1.67	1.75
Average score fast FLAIR	4.07	3.92	2.74	4.09	2.36	1.51	1.71	1.83
$Score_{fast\ FLAIR} > score_{T1}$ (%)	77.1	75.0	56.3	62.5	41.7	33.3	39.6	18.8
$Score_{fast\ FLAIR =} score_{T1}$ (%)	4.2	14.6	35.4	29.2	35.4	25.0	47.9	41.7
$Score_{fast\ FLAIR} > score_{T2}$ (%)	37.5	50.0	29.2	41.7	33.3	16.7	20.8	25.0
$Score_{fast\ FLAIR =} score_{T2}$ (%)	39.6	41.7	41.7	45.8	37.5	43.8	52.1	56.3

[a]Fast FLAIR significantly superior to this series at $P = 0.001$ level
[b]Fast FLAIR significantly inferior to this series at $P = 0.01$ level
[c]Fast FLAIR significantly inferior to this series at $P = 0.05$ level
[d]Fast FLAIR significantly superior to this series at $P = 0.01$ level
[e]Fast FLAIR significantly superior to this series at $P = 0.05$ level

tions did direct ranking of the sequences reveal a higher score on fast FLAIR than on T2 ($score_{fast\ FLAIR} > score_{T2}$: 36.8 %). The differentiation of the edema from brain was superior with fast FLAIR ($p < 0.01$), but the differentiation between tumor and edema (seen in 94 %) was superior with T1. Astrocytomas appeared very homogeneous on fast FLAIR resulting in the lowest inhomogeneity score of all sequences and in a bad detection of cystic components ($score_{fast\ FLAIR} > score_{T2}$: 14.7 %). The differences for inhomogeneity and the visualization of cystic components between fast FLAIR and the other series were all statistically significant ($p \leq 0.05$).

Low contrast enhancement

The low contrast enhancement group (Table 3) consisted of 9 histologically confirmed tumors (4 astrocytomas, 1 glioblastoma, 1 gangliocytoma, 1 lymphoma, 1 ependymoma, 1 pinealocytoma) and 3 non-histologically proven tumors (MRI diagnosis: astrocytomas) with an average contrast enhancement score of 0.88. The SI scores for fast FLAIR and T2 did not differ much (4.07 and 3.95, respectively). The differentiation of the tumor vs brain, however, was best using fast FLAIR ($p < 0.0001$ for fast FLAIR vs T1 and $p < 0.01$ for fast FLAIR vs T2).

Direct ranking of the sequences showed a superior score for the differentiation of the tumor vs brain on fast FLAIR than on T2 in 50.0 %. In only 8.3 % was T2 superior to fast FLAIR. Both, the delineation between tumor and edema (seen in 75 % of all observations) and between brain and edema, were more distinct with fast FLAIR (fast FLAIR vs T1 and T2: both $p < 0.02$).

Detection of cysts on the fast-FLAIR sequence was poor, probably due to the homogeneous aspect of the tumors resulting in the lowest average scores for cysts and inhomogeneity for fast FLAIR (2.38 and 1.63, respectively). The average scores of all observers for the detection of cystic components were lowest with fast FLAIR as compared with the other series.

Glioblastomas

Glioblastomas (Table 4) usually show a pronounced contrast enhancement (average score: 4.52); thus, the average SI score was significantly higher on T1 than on fast FLAIR or T2. Only in a few cases did direct ranking of the sequences show a higher SI score on fast FLAIR or T2 as compared with T1 ($score_{fast\ FLAIR} > score_{T1}$: 21.1 %; $score_{T2} > score_{T1}$: 15.4 %). Because of the high SI of the tumor compared with brain tissue, all other average scores related to the tumor's SI (differentiation of tumor vs brain and of tumor vs edema) were also the highest with T1.

Fast FLAIR and T2 had almost identical average scores for the differentiation of the tumor vs brain and

Table 4. Results for the glioblastoma group (52 observations per series). Average scores for all items and percentages found in the direct ranking of the scores of fast FLAIR vs T2

	SI	Differentiation Tumor – Brain	Differentiation Tumor – Edema	Differentiation Brain – Edema	Inhomogeneity	Cysts	Motion artifacts	Other artifacts
Average score T1	4.38[a]	4.63[b]	4.17[a]	2.77[c]	3.19[b]	3.25[b]	1.33[d]	1.67
Average score T2	3.96	3.84	3.48	4.10[c]	3.00[a]	2.82[b]	1.94	1.67
Average score fast FLAIR	3.96	3.81	3.76	4.80	2.65	2.04	1.75	1.78
$Score_{fast\ FLAIR} > score_{T2}$ (%)	25.0	32.7	46.2	51.9	15.4	9.6	21.2	23.1
$Score_{fast\ FLAIR =} score_{T2}$ (%)	51.9	38.5	25.0	40.4	48.1	36.5	42.3	59.6

[a]Fast FLAIR significantly inferior to this series at $P = 0.05$ level
[b]Fast FLAIR significantly inferior to this series at $P = 0.001$ level
[c]Fast FLAIR significantly superior to this series at $P = 0.001$ level
[d]Fast FLAIR significantly inferior to this series at $P = 0.01$ level

Table 5. Results for the meningioma group (40 observations per series). Average scores for all items and percentages found in the direct ranking of the scores of fast FLAIR vs T2

	SI	Differentiation Tumor – Brain	Differentiation Tumor – Edema	Differentiation Brain – Edema	Inhomogeneity	Cysts	Motion artifacts	Other artifacts
Average score T1	4.72[a]	4.88[a]	4.19	2.81[b]	1.95[b]	1.40	1.41	1.69[c]
Average score T2	3.58	3.33	3.59	3.93[d]	2.45	1.53	1.58	1.85
Average score fast FLAIR	3.73	3.45	4.00	4.62	2.53	1.42	1.53	1.90
$Score_{fast\ FLAIR} > score_{T2}$ (%)	20.0	35.0	35.0	45.0	30.0	17.5	25.0	25.0
$Score_{fast\ FLAIR =} score_{T2}$ (%)	67.5	40.0	40.0	40.0	40.0	60.0	40.0	55.0

[a]Fast FLAIR significantly inferior to this series at $P = 0.001$ level
[b]Fast FLAIR significantly superior to this series at $P = 0.001$ level
[c]Fast FLAIR significantly inferior to this series at $P = 0.05$ level
[d]Fast FLAIR significantly superior to this series at $P = 0.01$ level

Table 6. Results for the total of all patients and four evaluators (296 observations per series). Average scores for all items and percentages found in the direct ranking of the scores of fast FLAIR vs T1 and fast FLAIR vs T2

	SI	Differentiation Tumor – Brain	Differentiation Tumor – Edema	Differentiation Brain – Edema	Inhomogeneity	Cysts	Motion artifacts	Other artifacts
Average score T1	4.34[a]	4.31[a]	3.65[b]	2.59[c]	2.73[a]	2.38[a]	1.57[d]	1.79[e]
Average score T2	3.99	3.60[f]	2.99[d]	3.85[c]	2.56[a]	2.30[a]	1.76	1.79[e]
Average score fast FLAIR	4.03	3.77	3.24	4.38	2.29	1.67	1.73	1.89
$Score_{fast\ FLAIR} > score_{T1}$ (%)	24.7	20.9	36.1	66.6	19.9	16.6	33.4	31.1
$Score_{fast\ FLAIR =} score_{T1}$ (%)	26.0	28.7	31.1	24.7	35.8	38.2	48.6	49.7
$Score_{fast\ FLAIR} > score_{T2}$ (%)	28.0	35.8	36.1	45.9	20.6	11.5	24.7	26.4
$Score_{fast\ FLAIR =} score_{T2}$ (%)	54.4	41.6	38.9	39.2	43.2	44.6	44.3	56.8

[a]Fast FLAIR significantly inferior to this series at $P = 0.001$ level
[b]Fast FLAIR significantly inferior to this series at $P = 0.01$ level
[c]Fast FLAIR significantly superior to this series at $P = 0.001$ level
[d]Fast FLAIR significantly superior to this series at $P = 0.05$ level
[e]Fast FLAIR significantly inferior to this series at $P = 0.05$ level
[f]Fast FLAIR significantly superior to this series at $P = 0.01$ level

SI. Direct ranking of the sequences showed a superior demarcation of the tumor vs edema on fast FLAIR as compared with T2 in 46.2% and to T1 in 36.9%. The differentiation between brain and edema again was by far the best on fast FLAIR ($p < 0.001$). The average scores for inhomogeneity and for visualization of cysts of all evaluators were lowest for fast FLAIR.

Meningiomas

Meningiomas (Table 5) are characterized by a high and usually homogeneous contrast enhancement. Not surprisingly, they showed highest average scores for contrast enhancement (4.76) and SI on T1 (4.72) as compared with all other tumor types. Average scores for SI, differentiation of the tumor vs brain, and differentiation of the tumor vs edema were only slightly higher for fast FLAIR than for T2. The extent of the edema (present in 90%) was best detected using fast FLAIR. The average scores for the detection of cystic areas did not differ much between all series. Yet, fast FLAIR showed the highest inhomogeneity score of all sequences ($p = 0.001$ as compared with T1).

All patients pooled

With regard to all patients (Table 6), averaged across all tumor types, the T1 postcontrast series showed the highest SI most likely due to the high contrast enhancement of most of the tumors (average score: 3.94). However, the direct ranking of the sequences showed in 24.7% a higher SI score of the tumor on

fast FLAIR than on T1. Most of these tumors showed low contrast enhancement. Similarly, the average scores for the differentiation of the tumor vs brain and of the tumor vs edema were best for the T1 series (see Table 6). In contrast, the score for the differentiation of the tumor vs edema was highest for fast FLAIR: In 66.6% of patients, fast-FLAIR images were rated higher than T1 and in 45.9% higher than T2 (both $p < 0.0001$).

Most of the tumors appeared particularly homogeneous on fast FLAIR: 60.0% of the lesions were scored "markedly inhomogeneous" on T1 series, but only 36.6% were scored as such on fast FLAIR. The visualization of cystic parts was poorest on fast FLAIR: 63.8% of the tumors were rated "no cystic components at all" on fast FLAIR, but only 38.7% on T2 and 39.9% on T1(both $p < 0.0001$).

Motion artifacts were judged as compromising image evaluation in 17.2% for T1, in 13.9% for T2, and in 16.9% for fast FLAIR. All other artifacts (flow, susceptibility, and pulsations) were judged as compromising image evaluation in almost equivalent numbers of patients on all three sequences (13.9–15.9%). Neither for motion artifacts nor for all other types of artifacts were there significant differences in the number of observations that were judged to be compromised between the three sequences.

Discussion

Fast-FLAIR imaging was found to be superior to other MR sequences, especially in the evaluation of multiple sclerosis, due to the high contrast between CSF and adjacent lesions [11, 14, 15]. Accordingly, a high contrast between lesions and the surrounding structures using (fast-) FLAIR sequences has been seen in patients with intracranial tumors [4, 16]. Already the first description of FLAIR imaging of a brain tumor, a low-grade astrocytoma, emphasized that the extension of the lesion was more clearly delineated with fast FLAIR [6].

Despite these encouraging first results, there is only one study in the literature dealing exclusively with intracranial tumors [13]. In that study image evaluation was performed by directly comparing the different sequences: This procedure, however, can lead to overestimation of slight differences and can only be eliminated by a blinded analysis of the series. Most likely due to the smaller number of observers (two reviewers) and patients ($n = 34$), Tsuchiya et al. [13] did not perform a separate data analysis for different tumor types. Thus, their conclusion that "fast FLAIR images did not provide any additional information that was not available on the other sequences" (proton-density, T2, T1) may have been influenced by a relatively high number of strongly enhancing tumors in the study group (at least 26 of 34; tumor types incompletely categorized). Our data based on all tumors confirm Tsuchiya's results [13].

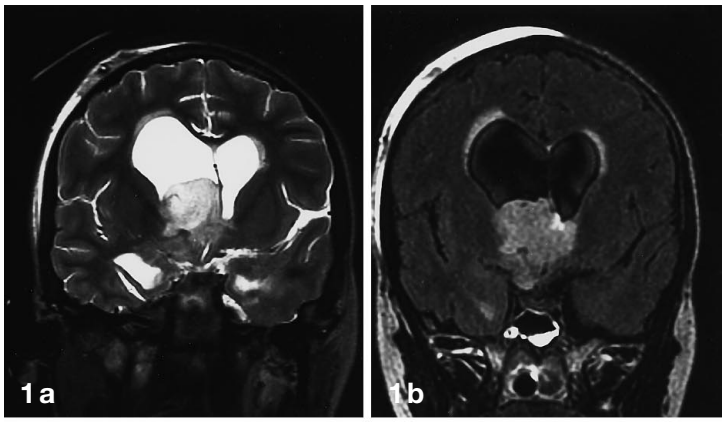
Separate data analysis for different tumor types, however, revealed the superiority of fast FLAIR for tumors with only poor contrast enhancement. In these tumors, T1-weighted images do not allow for exact delineation of tumor vs brain and vs surrounding edema. In these cases, we found fast FLAIR to be beneficial for the definition of the tumor's extent based on its high contrast to the surrounding structures (Figs. 1, 2). In the same way, the differentiation of tumor vs edema and of brain tissue vs edema was most obvious on fast FLAIR. We concluded that in patients with hypovascularized tumors, a fast FLAIR sequence can provide additional information and should be part of the examination. The results for the histologically proven astrocytomas ($n = 17$) were similar to those found for the tumor types with low contrast enhancement.

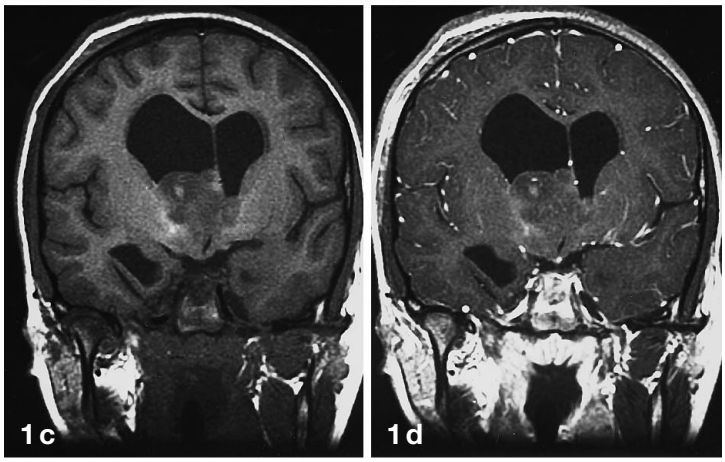
One of the limitations of fast-FLAIR imaging is the insufficient visualization of the inner structure of the tumor. Due to this, it is difficult to distinguish between the tumor itself and cystic or necrotic elements as described by DeCoene et al. [4]. Also Tsuchiya et al. [13] described a lower distinction between tumor and cystic or necrotic components with fast FLAIR as compared with T2- or proton-density-weighted images. Both components appear as hyperintense as the solid tumor parts (Fig. 3). This explains the very low scores for inhomogeneity and for rendering of cysts with fast FLAIR in this study. Only for meningiomas did we find the highest score for inhomogeneities with fast FLAIR as compared with the other series.

Meningiomas and glioblastomas are both characterized by a high signal enhancement after contrast application. In these lesions, fast FLAIR is not advantageous for the delineation of the tumor (Fig. 4). However, as for all other tumor types, it can be helpful for the demarcation of edema. This might be useful in those cases where its exact extent is important. For all other criteria, except for the inhomogeneity in meningiomas, fast-FLAIR images were equivalent to T2.

Motion artifacts were present in all series. The number of examinations in which image evaluation was found to be compromised by motion artifacts was equivalent with all sequences (T1 17.2%, T2 13.9%, fast FLAIR 16.9%). Flow artifacts are well known in (fast)-FLAIR series; Rydberg et al. [5] observed them in 15% of the images, and Keller et al. [17] noted "slightly more flow artifacts on fast FLAIR than on T1 and T2". In our study we did not differentiate between flow artifacts and other artifacts except for motion artifacts. Despite the relatively high incidence of these artifacts especially on fast FLAIR, they only rarely interfered with image evaluation.

With respect to the whole patient group, the results of our study are heterogeneous: There were higher average scores for fast FLAIR than for T2 for multiple criteria such as SI, demarcation of the tumor vs brain, tumor vs edema, and brain vs edema. However, this does not imply a general (slight) superiority of fast FLAIR but a higher diagnostic value of fast FLAIR in selected cases. In these patients, mainly those with poor contrast enhancement, the scores were markedly higher for fast FLAIR as compared with T2 for the more important criteria (SI, differentiation of the tumor from brain and from edema).





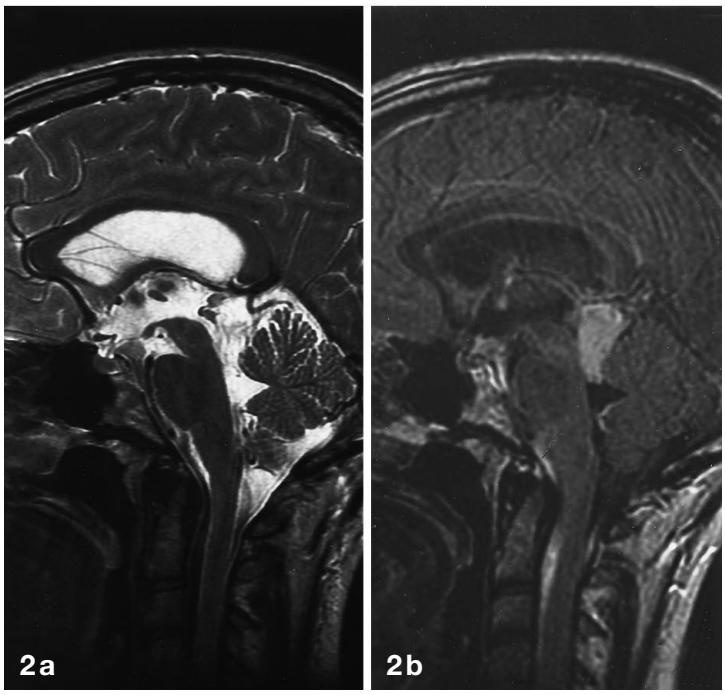


Fig. 1a–d. Astrocytoma with poor contrast enhancement. **a** T2-weighted fast spin-echo (SE) image (TR/TE = 4000/108 ms); **b** fast-FLAIR image (TR/TE = 11,002/132/2600 ms); T1-weighted SE **c** pre- and **d** post-contrast images (TR/TE = 600/15 ms). The tumor is better defined on the fast-FLAIR series than on T2-weighted images. On the T1 post-contrast image, the tumor is more difficult to differentiate due to its signal intensity which is almost identical to brain tissue

Fig. 2 a,b. Pinealocytoma. **a** T2-weighted fast SE image (TR/TE = 4000/108 ms); **b** fast-FLAIR image (TR/TE = 11,002/132/2600 ms). The tumor is much better delineated in the fast-FLAIR series than in the T2-series

The highly positive results of other authors refer mainly to demyelinating disorders and cannot be transferred to brain tumors. The major limitation of fast FLAIR is its limited information about the inner structure of the tumors; therefore, it cannot replace T2-weighted series but should be considered as an additional tool in the diagnosis of brain tumors which provides complementary information especially in tumors with poor contrast enhancement.

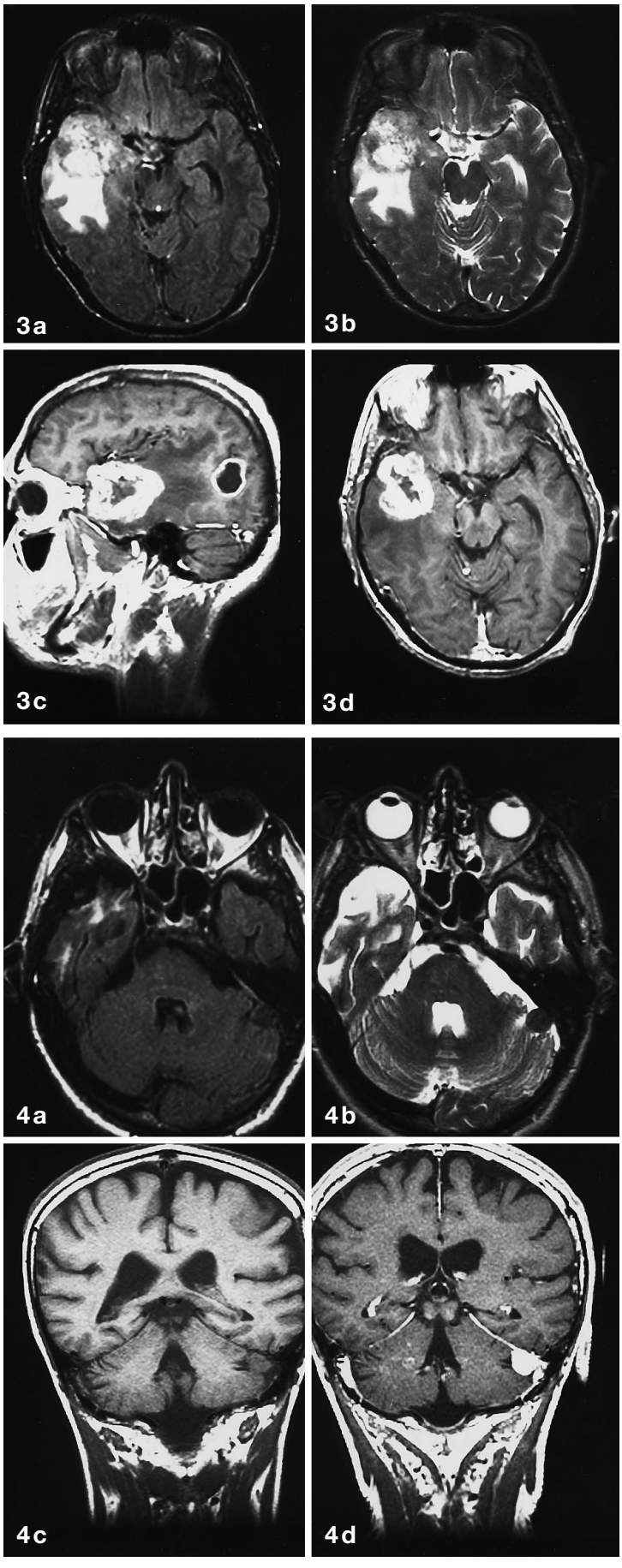


Fig. 3a–d. Multifocal glioblastoma. **a** Fast-FLAIR image (TR/TE = 11,002/132/2600 ms); **b** T2-weighted fast SE image (TR/TE = 4000/108 ms); **c,d** T1-weighted SE post-contrast images (TR/TE = 600/15 ms). The strongly enhancing lesion itself is best defined on the T1-post-contrast series. Fast FLAIR provides no relevant information

Fig. 4a–d. Meningioma. **a** Fast-FLAIR image (TR/TE = 11,002/132/2600 ms); **b** T2-weighted fast SE image (TR/TE = 4000/108 ms); T1-weighted SE **c** pre- and **d** post-contrast images (TR/TE = 600/15 ms). The lesion is best discerned on the T1-series after contrast. In fast FLAIR, definition of the tumor is much less pronounced than in the other series

Conclusion

Fast FLAIR constitutes an additional series for the visualization of brain tumors with low contrast enhancement only. It is helpful in defining the exact extension of the peritumoral edema in all brain tumors and it frequently renders the lesion with a greater conspicuity than T2 series. On the other hand, it is poor for imaging the inner structure of the tumor.

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