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Contrast Enhancement of Cerebral Infarcts. Incidence and Clinical Value in Different States of Cerebral Infarction

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Summary. Information obtained from CT scan after contrast administration was evaluated in 59 consecutive stroke patients. CT scans before and after contrast administration were performed 3 days and 2½ weeks after stroke. A plain CT scan was repeated 6 months later. Contrast enhancement was practically not seen on the first examination, but was seen in 46% on the second examination. There was a close relationship between the occurrence of contrast enhancement and the socalled "fogging effect". Contrast scanning gave additional information only when this effect was present. Plain CT scans 3 days after stroke were superior to contrast scans taken at any time for detecting and visualizing cerebral infarcts.

Key words: Computed tomography – Contrast enhancement – Fogging effect – Completed stroke – Cerebral infarct

Introduction

Intravenous injection of iodine contrast media is widely used to localize and to estimate the size and extension of cerebral infarcts, in particular when these are not seen on plain CT scan [2–5, 7–9, 13, 14, 17–19]. The use of iodine contrast scans in stroke patients is increasingly debated [7, 10, 13, 15, 17], and some investigators even consider these highly osmolar materials to be harmfull, worsening the prognosis [10]. If so, contrast media should be used only if the information yielded is of definite clinical value. In a 2-year period we have investigated a series of stroke patients with repeated CT scans both with and without administration of iodine contrast media. On the basis of this group the present analysis was performed in order to determine if contrast scans compared to plain scans give additional information of significant importance.

Material and Method

The study is prospective and consecutive comprising 59 patients below the age or 75, all suffering from completed stroke. Transient ischemic attacks (TIA) and intracerebral hematomas were not included in the study.

The diagnosis was established in all cases by clinical neurological examination, electroencephalography, 99 m technetium isotope brain scintigraphy, cerebral angiography, measurements of the regional cerebral blood flow (rCBF) and computed tomography (CT).

All patients were examined with a EMI CT 1010 scanner using the 160 × 160 matrix.

CT was performed in all cases within 1 week after the onset of stroke. A second CT was performed approximately 2 weeks later and a third approximately 6 months after the stroke. The first and second CT scans were performed without contrast and were repeated after intravenous infusion of 60 ml Isopaque® 440. The duration of the infusion was about 5 min and the CT was performed immediately after the infusion. The absorption values on contrast scans were measured in areas where enhancement was most pronounced. The density was given as an average of the absorption values in a circle with a radius varying from 3.8–9.5 mm, depending on the size of the lesion. The density in corresponding areas on the plain scans was measured in the same manner. The absorption values thus obtained in the first and second examina-

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Table 1. The increase in density from the first to the second CT scan before and after contrast administration. The density in the contralateral normal area is used as reference

Case	Increase in HU in lesions after contrast infusion at CT-I	Difference in HU between lesions and contralateral normal area after contrast infusion at CT-I	Difference in HU between lesions and contra-lateral normal area at CT-II on plain CT	Increase in HU in lesions after contrast infusion CT-II	Difference in HU between lesions and contra-lateral normal area after contrast infusion at CT-II
1	3.05	− 5.52	1.03[ab]	14.96[c]	11.55
2	1.27	− 16.16	− 12.15	18.48[c]	5.20
3	0.02	− 16.30	0.11[ab]	36.34[c]	31.52
4	−	−	− 8.22	23.85[c]	14.30
5	3.07	− 6.89	1.92[ab]	10.81[c]	8.89
6	6.79	− 8.73	0.68[ab]	20.19[c]	15.60
7	1.25	− 9.77	2.44[ab]	16.25[c]	12.16
8	−	−	0.70[a]	23.29[c]	21.51
9	2.66	− 8.66	− 6.44	21.58[c]	15.14
10	1.81	− 17.69	1.49[ab]	18.95[c]	17.14
11	3.59	− 10.21	2.92[a]	21.07[c]	14.11
12	0.85	− 11.34	0.92[ab]	30.22[c]	28.00
13	−	−	0.50	15.81[c]	14.47
14	−	−	3.05[a]	5.89[c]	2.40
15	1.09	− 12.11	1.32[ab]	8.89[c]	9.03
16	2.00	− 14.27	0.50[ab]	24.85[c]	25.62
17	2.29	− 6.48	3.52[a]	17.03[c]	10.97
18	2.89	− 4.92	0.07[ab]	16.33[c]	17.95
19	8.55	− 10.62	3.20[ab]	13.44[c]	9.12
20	3.00	− 14.29	3.47[ab]	10.76[c]	5.03
21	0.24	− 8.01	2.88[ab]	16.14[c]	10.32
22	2.00	− 4.67	− 7.42	2.22	− 6.00
23	0.45	− 9.84	− 7.57	1.45	− 6.79
24	6.11	− 14.00	0.67[ab]	7.23[c]	2.11
25	1.24	− 6.95	− 7.19	0.24	− 6.53
26	0.00	− 9.45	− 14.66	0.22	− 15.34
27	0.00	− 12.20	− 7.92	16.25[c]	5.19
28	0.89	− 10.00	3.67[ab]	25.22[c]	19.22
29	0.67	− 16.97	− 9.54	1.56	− 10.00
30	0.22	− 12.89	− 10.45	− 1.33	− 14.00
31	2.57	− 17.67	− 21.05	2.79	− 17.09
32	1.00	− 14.22	− 10.56	− 1.22	− 11.45
33	1.90	− 11.72	− 5.53	3.15	3.90
34	0.05	− 14.85	− 6.15	2.29	3.71

[a] Patients showing the fogging effect
[ab] Patients where the infarcts could not be identified due to the fogging effect
[c] Patients showing significant contrast enhancement.

tion were compared in order to evaluate the degree of enhancement. For comparison, the density in the normal contralateral areas was likewise determined on the first and second examination.

We consider changes in density exceeding 4.5 HU as significant, based on normal material published recently [16].

Results

The interval between stroke and first CT examination averaged 79 h (range 38–124 h); 17 days (range 13–25 days) between stroke and second CT; and 6 months between stroke and third CT.

First CT Examination

Plain scans were performed on 59 patients, of whom 54 also had contrast scan. A hypodense area, corresponding to the neurological symptoms and signs, was seen on 38 of the plain scans. A contrast scan was performed on 36 of these patients. There was a slight, but significantly increased density in the lesions of only three patients after contrast administration (from 6.11–8.55 HU) (Table 1). Enhancement did not occur in patients without a hypodense lesion.

Second CT Examination

Plain scans were performed on 52 patients. Contrast scans were performed on all (five patients died during

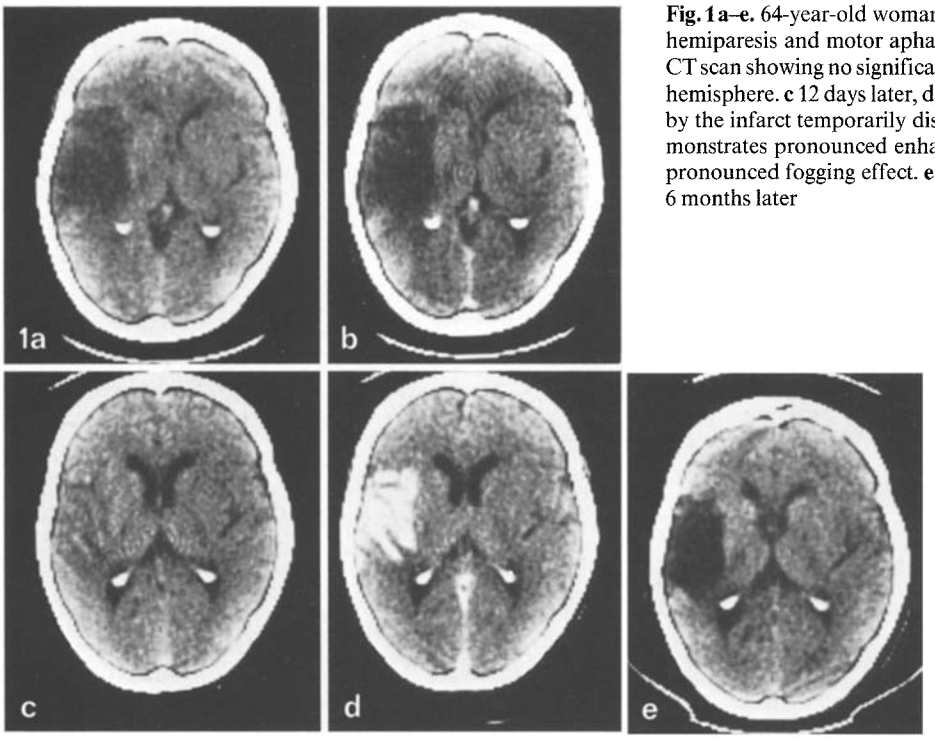


Fig. 1 a–e. 64-year-old woman. Completed stroke with severe right hemiparesis and motor aphasia. **a** and **b** Early plain and contrast CT scan showing no significant enhancement of large infarct in left hemisphere. **c** 12 days later, demonstrates the fogging effect whereby the infarct temporarily disappears on the plain CT scan. **d** Demonstrates pronounced enhancement in infarct corresponding to pronounced fogging effect. **e** shows final infarct on plain CT scan 6 months later

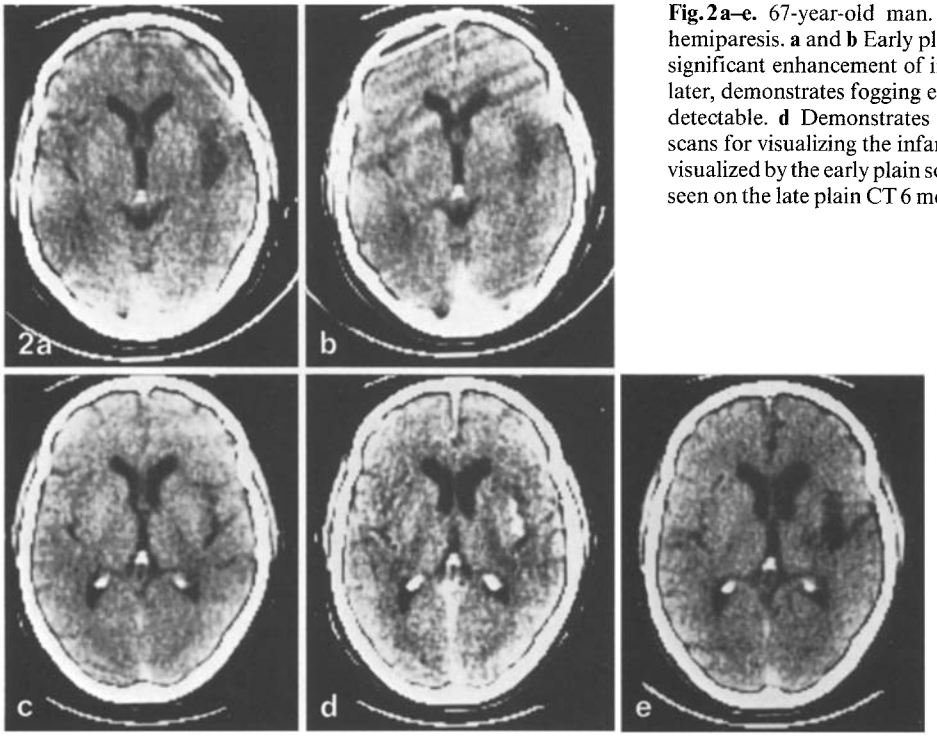


Fig. 2 a–e. 67-year-old man. Completed stroke with severe left hemiparesis. **a** and **b** Early plain and contrast CT scan showing no significant enhancement of infarct in right hemisphere. **c** 14 days later, demonstrates fogging effect on plain scan. The infarct is not detectable. **d** Demonstrates the sparse information on contrast scans for visualizing the infarcted area. The infarct is much better visualized by the early plain scan which is very much like the infarct seen on the late plain CT 6 months after stroke

the period between the first and second CT examination; in two other patients the second CT was not possible). A hypodense area, corresponding to the neurological symptoms and signs was seen in 18 patients. They were also seen on the first plain scans but, in most cases, appeared to be considerably smaller on the second plain scan because of the fogging effect (Fogging effect: the phenomenon whereby hypodense lesions become isodense or close to isodense during the 2nd and 3rd week after stroke [1, 16]).

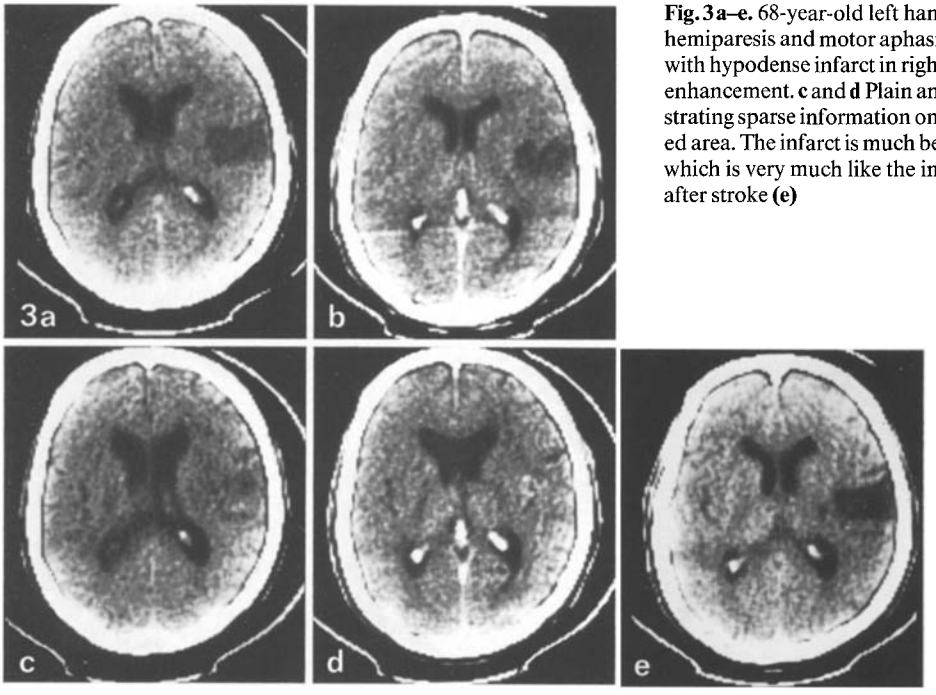


Fig. 3 a–e. 68-year-old left handed man. Completed stroke with left hemiparesis and motor aphasia. **a** and **b** Plain and contrast CT scan with hypodense infarct in right hemisphere. No significant contrast enhancement. **c** and **d** Plain and contrast scans 13 days later demonstrating sparse information on contrast scans for visualizing infarcted area. The infarct is much better visualized by early plain CT scan which is very much like the infarct seen on late plain CT 6 months after stroke **(e)**

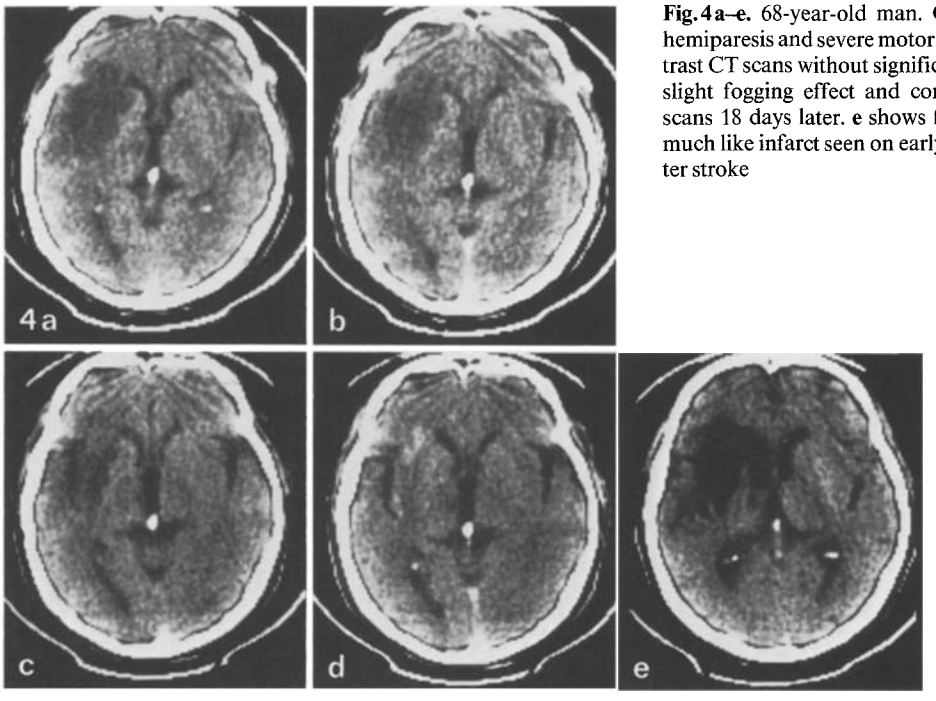


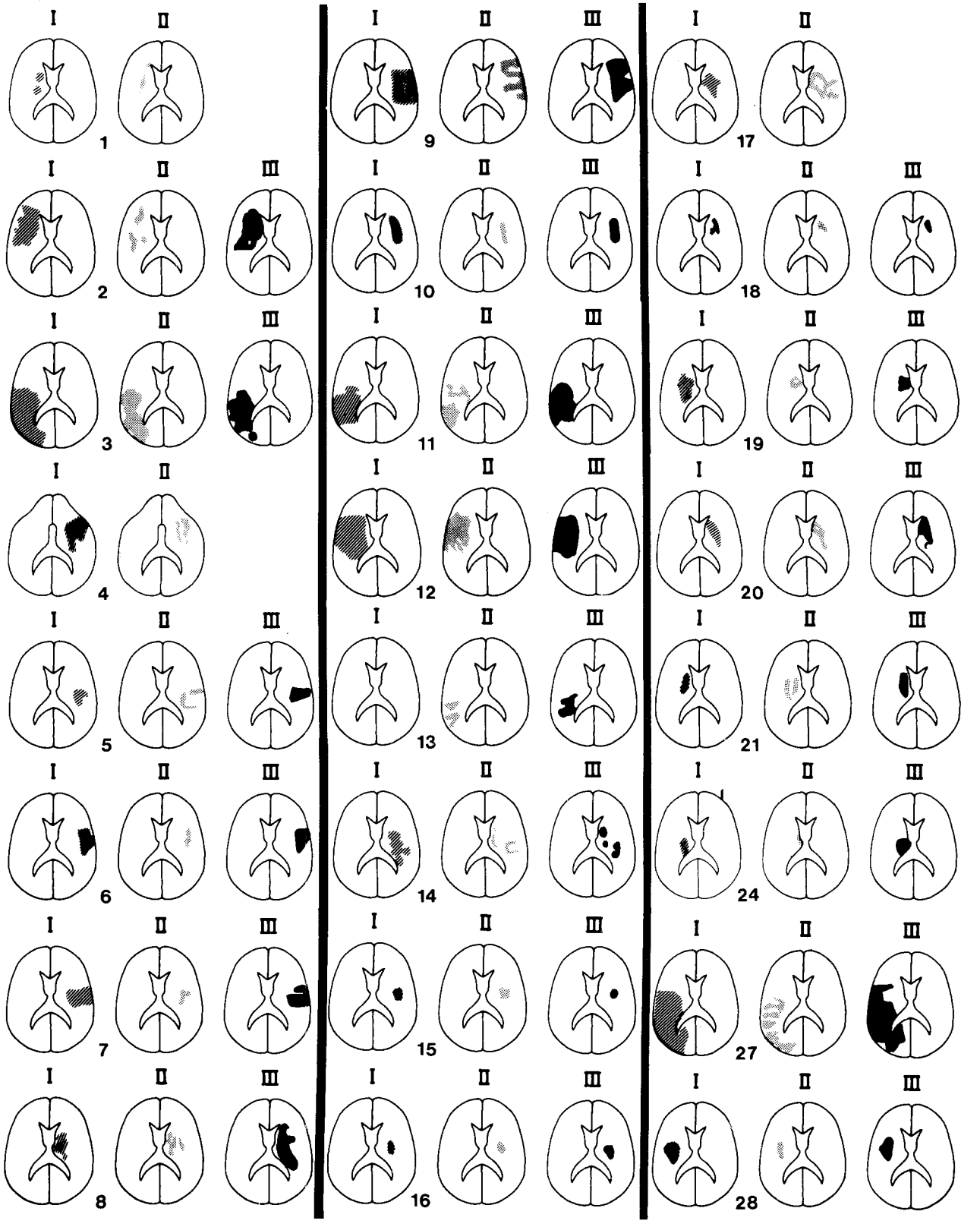
Fig. 4 a–e. 68-year-old man. Completed stroke with severe right hemiparesis and severe motor aphasia. **a** and **b** Early plain and contrast CT scans without significant enhancement. **c** and **d** show only slight fogging effect and corresponding slight enhancement on scans 18 days later. **e** shows final hypodense area 6 months later much like infarct seen on early plain CT scan performed 3 days after stroke

Clearly hypodense areas, seen on the first CT of 15 patients, could not be identified on the second plain scan, also because of the fogging effect. (Figs. 1 and 2). All these infarcts, which disappeared partially or totally on the second plain scan, were clearly seen on the third plain CT scan performed 6 months after the stroke (Figs. 1–4).

Of the 33 hypodense lesions 23 (70%) seen on the first CT enhanced on the second CT after contrast administration (from 5.89–36.34 HU) (Tables 1 and 2; Figs. 1–4).

A focal hypodense lesion was not seen on the first or second CT scan in 19 cases, in nine of which a hypodense lesion concordant with the clinical symp-

Table 2. 24 patients (in Table 1) showing significant contrast enhancement at the second CT scan approximately 2–3 weeks after stroke. I. Early plain CT approximately 3 days after stroke. II. Contrast scan at second examination 2–3 weeks after stroke. III. Plain CT approximately 6 months later. The table illustrates the resemblance between the lesion on the early plain CT and the final lesion seen on plain CT 6 months later. The enhanced areas on the second CT are considerably smaller in most cases



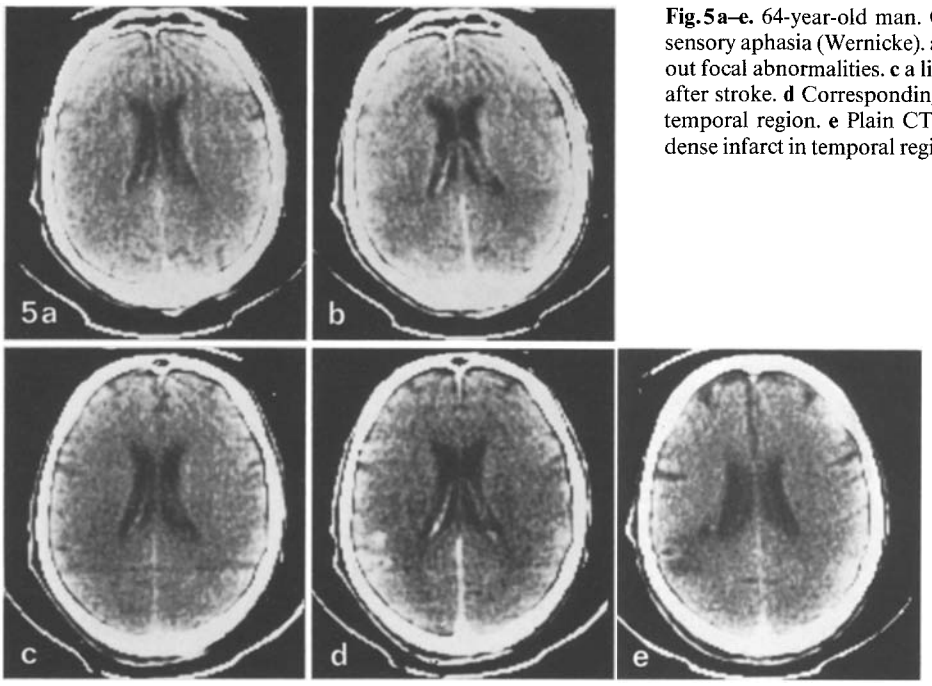


Fig. 5a–e. 64-year-old man. Completed stroke with symptoms of sensory aphasia (Wernicke). **a** and **b** Plain and contrast scans without focal abnormalities. **c** a likewise normal plain CT scan 15 days after stroke. **d** Corresponding contrast scan with enhancement in temporal region. **e** Plain CT scan 6 months later showing hypodense infarct in temporal region

toms and signs, appeared on the third CT scan. In only one of the 19 cases was the infarct demonstrated as an enhanced area on the second CT scan, despite the normal plain scan (Fig. 5).

Patterns of Contrast Enhancement

The appearance of the enhanced areas, compared to the hypodense lesions seen on the first and third CT scans, can be found in Table 2. The enhanced areas showed a greatly varying pattern:

1. Scattered patchy islands (9 cases),
2. homogenous areas within the lesion (6 cases),
3. ring-like structures in the periphery of the lesion (2 cases),
4. areas localized to and outlining deep or cortical grey matter, grey matter enhancement (7 cases) [11].

Comparing the enhanced areas to the final hypodense infarcts on the third CT scan performed 6 months after the stroke, it appeared clear that the enhanced areas in most cases were substantially smaller than the final infarcts (Table 2; Figs. 2 and 3).

Fogging Effect and Contrast Enhancement

Fogging effect was seen in 19 cases. All of these (Figs. 1 and 2) showed contrast enhancement on the second CT scan, while cases not showing the fogging effect enhanced slightly in only 4 of 33 cases (Fig. 4).

Discussion

When CT was performed within the first week after stroke, contrast enhancement was practically not seen in this unselected series. We must therefore conclude that CT scans after contrast infusion in stroke patients do not give any additional information in the early stage of stroke.

An infarct was demonstrated on the first early CT scan in half of the cases, but only ¾ of these infarcts enhanced on the second examination. In only one of the 59 cases did a contrast CT scan reveal an infarct which was not detectable on the first two plain scans. Thus, the early plain CT scan was superior to the contrast scan for detecting an infarct and in this respect contrast scans were not of any additional help.

When an infarct was seen on the first and/or second plain scan, enhancement was seen in 70% of the cases. This is concordant whith the findings of others [3, 6, 12, 17]. Caillé et al. [3] demonstrated enhancement in 10% during the first week, 25% during the second, 60% during the third and 67% during the fourth week in a study of 231 cases. It is most likely that all infarcts enhance during their evolution from the early state with tissue necrosis until the final scar tissue is established. The time interval between stroke and when contrast enhancement reaches a maximum, probably varies which explains why enhancement was not seen in 30% of the cases. These cases might instead exhibit contrast enhancement in the fourth week or even later.

During the 2nd and 3rd week after stroke the fogging effect reaches a maximum [1]. Because of the fogging effect infarcts, during that period, may disappear temporarily on plain CT, and several (even large) infarcts may be underestimated or even overlooked. The fogging effect however coincides with the occurrence of contrast enhancement. Hence, infarcts that temporarily disappear on plain CT may be visualized if contrast scans are performed. The fogging effect and contrast enhancement both reach their maximum when the formation of granulation tissue in the reabsorption process of the necrotic brain tissue also reaches a maximum. Therefore they might both be a manifestation of this pathophysiological process in which the capillaries are highly permeable without a tight barrier. This might explain why infarcts with pronounced enhancement also exhibit pronounced fogging effect and vice versa. If information about the size and location of an infarct is needed a contrast scan is therefore advisable if the investigation is performed during the 2nd to 4th week after the onset of symptoms.

It should be emphasized however, that the infarcts in most cases are only partially visualized by contrast enhancement. The entire infarct is still much better demonstrated by an early plain CT scan which outlines nearly the same area as the final scar tissue seen on a late CT scan 6 months after stroke (Table 2).

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