Radiological abnormalities in temporal lobe epilepsy with clinicopathological correlations

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SYNOPSIS In 73 patients with drug-resistant temporal lobe epilepsy submitted to an unilateral anterior temporal lobectomy the radiographs were studied to see if there were any correlation with the pathology subsequently found and with the outcome of the operation. A small middle cranial fossa, focal calcification, and temporal horn displacement are often better indices of the underlying pathology than temporal horn dilatation alone. In a small number of cases, however, radiological changes were seen on the side opposite to an unilateral EEG focus, thus suggesting bilateral disease.

There is now good evidence that epilepsy arising from the temporal lobe often has a structural basis rather than being idiopathic (Falconer *et al.*, 1964; Falconer, 1969). The epileptogenic lesions are usually small and often in the region of Ammon's horn (hippocampus). The most frequent lesion is sclerosis of the hippocampus and neighbouring structures—mesial temporal sclerosis (Falconer *et al.*, 1964; Margerison and Corsellis, 1966). Small hamartomas (Cavanagh, 1958; Falconer and Cavanagh, 1959), scars and infarcts, and non-specific gliosis without neuronal abnormalities are less commonly encountered. Rarely, other discrete lesions, such as small capillary angiomas and epidermoid cysts, may also occur.

Falconer and Taylor (1968) reported 100 consecutive patients in whom gross space-occupying lesions were excluded by neuroradiological studies, and who were submitted to an unilateral temporal lobectomy and followed up for two to 12 years. They related the clinical outcome to four groups of pathological substrates. Mesial temporal sclerosis (MTS) was present in half of these patients and the best results of

surgery were in this group. Hamartomas, which may be regarded as small developmental abnormalities, occurred in 22% of cases. They also had a good prognosis for relief of seizures, but were less likely to be associated with improvement in social adaptation. Miscellaneous scars and infarcts occurred in about 12% and the remainder had no specific neuronal pathology. A good prognosis after operation was less common in the latter two categories. These patients all had a predominantly unilateral electroencephalographic (EEG) spiking focus but no detailed consideration was given to the radiological findings in their study. The radiological investigations, therefore, have now been reviewed in an attempt to assess their value in identifying the site and nature of the pathological process. It was presumed before this review that a good therapeutic result meant that the correct temporal lobe had been resected, while a poor therapeutic result cast doubts on this, especially if it were shown that there were radiological abnormalities on the opposite side.

METHOD

Two of us (R.L.N. and S.H.S.) studied blind the plain skull films and lumbar pneumoencephalograms of 73 English-speaking patients from the series reported by Falconer and Taylor (1968). Neither the reports nor the clinical notes were consulted in the

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(Accepted 21 October 1974.)

initial assessment and the cases were studied in random order. The two assessors had no prior knowledge of the individual patients in this series—the radiographs had previously been reported by R.D.H. and the operations performed by M.A.F. The remaining 27 patients of the earlier series were excluded because the radiographs were either no longer available or were incomplete. All patients were examined on a skull table with anode–film distance of 36 in (90 cm).

PLAIN SKULL RADIOGRAPHS In the plain skull films the following were recorded: (1) skull symmetry, with particular attention to vault thickness and hemiatrophy; (2) symmetry and size of the middle cranial fossae; (3) focal areas of abnormal calcification.

The size of the middle fossa was assessed as normal or small on the basal and half-axial views. Special

emphasis was given to the radius of the curve of the anterior margin of the fossa as seen on the basal view and to the configuration of the floor of the fossa in the half-axial projection.

In the basal view, the middle fossa was regarded as small on one side if there was distinct asymmetry in appearance without general skull asymmetry, taking into account the curve of the anterior part of the fossa and the difference in width of the skull base between the midline and the inner table of the temporal part of the vault. A tracing of one side reversed to superimpose over the other side on the film assists in this assessment. In stating that a middle fossa was small we imply a relative difference between the two sides, not necessarily pathological.

The relative heights of the petrous ridge in the half-axial view, the degree of thickening of the temporal part of the vaults, and the amount of pneumatization of the temporal bone were also taken

FIG. 1 Two marked examples of small middle cranial fossas. (a) Basal view showing small middle fossa on left side in a 14 year old girl with mesial temporal sclerosis, who was completely relieved by subsequent left temporal lobectomy. The curve of the sphenoidal ridge on each side is indicated by arrows. (b) Half axial view showing thick temporal vault on right side and shallow temporal fossa in an 11 year old boy with an atrophic temporal lobe with porencephaly. The difference in the floor of the middle fossa on the two sides is indicated by arrows, while the right petrous ridge is relatively higher than the left. The patient was improved by right temporal lobectomy.

into consideration. Two marked examples of small middle fossa on one side are shown in Fig. 1.

ENCEPHALOGRAPHY The features assessed include: (1) the size and symmetry of the ventricular system as a whole; (2) the size, shape, and position of the temporal horn (Lindgren, 1947, 1948.)

The following measurements were made: (a) body of the lateral ventricle—transverse and diagonal width; (b) septum—caudate line; (c) width of third ventricle; (d) width of lateral cleft of temporal horn.

Separate assessments for the anterior horn and trigone of the lateral ventricles were made on the general appearances. The following measurements were accepted as the upper limits of normal ranges:

Third ventricular width: 9 mm
(Robertson, 1959)

Transverse ventricular width: 45 mm
(Davidoff and Dyke, 1946)

Diagonal width of lateral ventricle: 20 mm
(Davies and Falconer, 1943)

Septum—caudate line: 14 mm
(Troland *et al.*, 1946)

Lateral cleft of temporal horn: 4 mm
(Van Buren *et al.*, 1956).

The width of the lateral cleft of the temporal horn was measured in the half-axial view where the cleft is narrowest just behind the flared tip of the horn. The presence or absence of an indentation of the lateral cleft by the collateral eminence was also noted. Whenever the lateral cleft measurements were more than 4 mm we considered the temporal horn to be dilated.

The findings were then correlated with the side of operation, the pathology of the resected temporal lobes, and the clinical outcome. Pathological lesions were grouped as mesial temporal sclerosis (MTS), hamartomas (HAM), miscellaneous lesions (MISC) such as scars and infarcts, and non-specific gliosis (NON-SP). Clinical outcome (for seizure relief only) was graded:

- I Fit free postoperatively
- II Marked improvement
- III Partial improvement
- IV No change

The mean age at operation was 26.1 years (range 11–46 years). There were 45 males and 28 females.

RESULTS

A. RADIOLOGICAL FINDINGS AND LATERALITY

Radiological abnormalities were present in 51 patients (70%) (Table 1). Unilateral abnormalities on plain skull radiography corresponded

with the side chosen for operation in 28 of the total of 37. On encephalography, unilateral abnormalities corresponded with the operated side in 29 of a total of 44. The remainder showed bilateral changes, or changes on the non-operated side only.

TABLE 1
RADIOLOGICAL FINDINGS IN TEMPORAL LOBE EPILEPSY*

Skull radiography		Encephalography	
Normal	36	Normal	29
Abnormal	37	Abnormal	44
Skull radiographic abnormalities		Encephalographic abnormalities	
Hemiatrophy	4	Atrophy	3
Middle fossa changes		Hemiatrophy	2
a. Operated side small	22	Dilated temporal horn	
b. Non-operated side small	4	a. Operated side	21
c. Bilateral abnormalities	4	b. Non-operated side	10
		c. Bilateral	2
Calcification	3	Displacement of temporal horn	6

* N = 73. Skull radiographs and encephalogram both normal = 22 (30%).

PLAIN SKULL RADIOGRAPHS

HEMIATROPHY Eighteen cases had general skull asymmetry, within normal limits. Four had definite hemicranial atrophy and the side of hemiatrophy was the side of the operation in all four.

MIDDLE FOSSA CHANGES 1. *Unilateral* Twenty-two patients were assessed as having a small middle fossa on one side. The middle fossa floor was small on the operated side in 12 instances. In some of these, other changes were also present, including a high petrous ridge (nine), thickening of the temporal vault (three), and excessive temporal air cells (two). Also on the operated side, a high petrous ridge alone was noted in seven, thickening of the temporal vault in one, and excessive pneumatization in two.

On the non-operated side (when the operated side was normal), we found two examples of small middle fossa floor in the basal view and two of high petrous ridge shown by the half-axial and posteroanterior projections.

2. *Bilateral* Bilateral changes which were detected included: (a) Two patients with thickened temporal vault and excessive pneumatization of equal degree on both sides; (b) two patients with a small middle fossa floor on the operated side but a high petrous ridge on the other side.

CALCIFICATION There were three patients with anterior temporal calcification (Fig. 3a). The calcified areas were 0.5–1 cm diameter and all were unilateral. All proved to be hamartomas.

ENCEPHALOGRAPHIC FINDINGS

ATROPHY AND HEMIATROPHY The bodies of the lateral ventricles were symmetrical in 45 cases and asymmetrical in 28. In three patients there was symmetrical dilatation with other features sufficient to support a radiological diagnosis of mild cerebral atrophy. Of the asymmetrical cases, two had definite hemiatrophy and others had slight degrees of lateral ventricular enlargement in association with a more marked degree of temporal enlargement. (In two cases the anterior horn alone was enlarged on one side when the body was not, and the trigone was enlarged when the body was not in three cases. All these had temporal horn dilatation. There were no cysts, ventricular diverticula, or midline displacements of note.)

TEMPORAL HORN ABNORMALITIES Apart from the patients with cerebral atrophy or hemiatrophy, there were 33 patients with dilatation of one or both temporal horns. Two had bilateral enlargement and in these the remainder of the ventricular system was normal. In the 31 unilateral cases, there was some enlargement of the ipsilateral ventricle in 15 (45%). The left temporal horn was more commonly dilated than the right.

In 10 patients, a dilated temporal horn was present on the non-operated side with a normal temporal horn on the side of resection. These films were reviewed a second time by one of us (S.H.S.) without access to the original interpretation and without any clinical or pathological data.

In one, the difference between the two sides was slight and the larger temporal horn may have

been at the upper limit of normal range. In the other nine, the abnormality was confirmed.

Displacement with distortion of the temporal horn was seen in six instances, suggesting a hamartoma or sclerosis. These displacements involved only the anterior part of the temporal horn. The displacement was towards the midline in two, upwards and laterally in four.

The radiological demonstration of the collateral eminence of the temporal horn was studied. This, a normal anatomical structure of variable proportion, sometimes causes a demonstrable indentation on the inferolateral aspect of the temporal horn. It usually corresponds with the collateral fissure on the inferior aspect of the temporal lobe. In this series it was unilaterally prominent in 16 cases and in none was it prominent on both sides. In 12 patients with a prominent collateral eminence, the temporal horn was dilated on the same side. In four, the temporal horn on the same side was normal in size.

B. PATHOLOGY

In the 22 patients with both normal skull radiographs and normal lumbar pneumoencephalograms, focal pathology was subsequently found at operation in all but two. The distribution was mesial temporal sclerosis 13 (59%); hamartomas 4 (18%); miscellaneous 3 (14%); non-specific 2 (9%).

These findings form a basis for comparison with those with abnormal radiographs. The pathology associated with the plain radiographic changes is shown in Table 2. Hemiatrophy occurred in MTS, hamartomas and non-specific gliosis. Mesial temporal sclerosis occurred in association with changes suggesting a small middle fossa on the same side in 12 cases and on the opposite side in three cases. All the calcified lesions were hamartomas.

The pathology associated with encephalographic abnormalities is shown in Table 3. In atrophy and hemiatrophy, the histological findings were either MTS, or non-specific gliosis. There were positive associations ($P < 0.01$) of mesial temporal sclerosis or non-specific pathology with temporal horn dilatation, and of hamartomas with temporal horn displacement. Typical changes in MTS and hamartomas are illustrated in Figures 2 and 3.

(a) Small middle cranial fossa (left side). Basal view. Female, aged 36 years. Infantile convulsions at 18 months.

(b) Dilatation of left temporal horn (with elevation of petrous ridge). Antero-posterior view. Female, aged 19 years. Precipitate birth and infantile convulsions beginning at 3 months of age. The left middle cranial fossa floor was also small.

(c) Dilated left temporal horn with appearance of smallness of the hippocampus compared with the other side (arrow). Antero-posterior view. Female, aged 18 years. Infantile convulsions after head injury at 2 years of age.

(d) Gross temporal lobe atrophy with dilated right temporal horn and small right hemicranium. Anteroposterior view. Female, aged 24 years. Convulsions at the age of 5 years associated with right temporal otogenic abscess.

FIG. 2 Features of mesial temporal sclerosis in temporal lobe epilepsy.

FIG. 3 Features of hamartomas in temporal lobe epilepsy. (a, top left) Calcified lesion (arrow) in medial part of left temporal lobe, elevating temporal horn. Associated small middle cranial fossa. Anteroposterior view. Male, aged 23 years. (b, top right) Hamartoma indenting hippocampal aspect of left temporal horn (arrow). Anteroposterior view. Male, aged 44 years. (c, bottom right) Lateral displacement of right temporal horn with indentation of hippocampal aspect (arrow). Half-axial view. Male, aged 19 years.

C. CLINICAL OUTCOME

In the radiologically normal group (22), the clinical outcome regarding seizure relief was graded as follows:

grade	I	12	} 16 (73%)
	II	4	
	III	4	} 6 (27%)
	IV	2	

In Table 4, the abnormalities found in plain radiographs of skull are related to clinical outcome. All the patients with calcified lesions (hamartomas) did well (outcome grades I and II). Of those with unilateral middle fossa changes on the operated side (mainly MTS or non-specific pathology), there was no significant difference in outcome compared with the group with normal radiographs.

The relationship of encephalographic change to clinical outcome is shown in Table 5. Those

TABLE 2
CORRELATION OF PLAIN RADIOGRAPHS OF SKULL
AND PATHOLOGY

Radiological findings	Patients (no.)	Pathology			
		MTS	HAM	MISC	NON-SP
Hemiatrophy	4	2	1	—	1
Small middle fossa					
Operated side	22	12	1	2	7
Non-operated side	4	3	—	—	1
Bilateral	4	7	—	—	—
Calcification	3	—	3	—	—
Normal	36	18	5	3	10

with cerebral atrophy or hemiatrophy tended to have a poor outcome, while those with temporal horn displacement (mainly hamartoma) had a favourable one. There was no significant difference in outcome between those who had slight to

TABLE 3

CORRELATION OF ENCEPHALOGRAPHIC CHANGES AND PATHOLOGY

Radiological findings	Patients (no.)	Pathology			
		MTS	HAM	MISC	NON-SP
Generalized atrophy	3	2	—	—	1
Hemiatrophy	2	1	—	—	1
Dilated temporal horn					
Operated side	21	15	1	—	5
Bilateral	12	1	—	—	1
Non-operated side	10	4	—	1	5
Temporal horn displacement	6	2	3	—	1
Normal	29	13	6	4	6

TABLE 4

CORRELATION OF PLAIN RADIOGRAPHS OF SKULL AND CLINICAL OUTCOME

Radiological findings	Patients (no.)	Clinical outcome (grade)			
		I	II	III	IV
Hemiatrophy	4	2	—	2	—
Small middle fossa					
Operated side	22	10	7	3	2
Non-operated side	4	1	1	—	2
Bilateral	4	2	2	—	—
Calcification	3	2	1	—	—
Normal	36	16	7	6	7

TABLE 5

ENCEPHALOGRAPHIC CHANGES AND CLINICAL OUTCOME

Radiological findings	Patients (no.)	Clinical outcome (grade)			
		I	II	III	IV
Generalized atrophy	3	—	1	1	1
Hemiatrophy	2	—	—	2	—
Dilated temporal horn					
Operated side	21	8	7	5	1
Non-operated side	10	4	2	—	4
Bilateral	2	1	—	—	1
Temporal horn displacement	6	3	2	—	1
Normal encephalogram	29	17	6	3	3

poral lobe epilepsy, perhaps because of the problems involved in assessment. The changes are often subtle and largely determined by comparison between the two sides. In this paper we have not regarded minimal asymmetry of the temporal horns as an indication of pathology. Some instances of possible bilateral skull or encephalographic change may have gone undetected. In the absence of plain film changes we feel we cannot diagnose a lesion on the basis of a small temporal horn, as shown on encephalography, although it is well known that some cases of mesial temporal sclerosis with an atrophic hippocampus are associated with a small temporal horn as seen in the half axial view.

The abnormalities found were (a) atrophic changes associated with a small temporal lobe—that is, a small middle fossa with or without temporal horn dilatation; (b) changes of small discrete space-occupying lesions; or (c) calcification.

ATROPHIC CHANGES Cerebral atrophy or hemiatrophy was present in a few patients (Table 3). It was hoped preoperatively that the anterior temporal lesions found in these patients were responsible for epileptic attacks and that improvement would follow anterior temporal lobectomy, even though disease was clearly more widespread. Our findings suggest that a good outcome (grades I and II) is unlikely in such patients, although an exception to this general finding has since been observed.

Middle fossa changes are often less obvious than those of hemiatrophy, but sometimes they are striking. A small temporal lobe is a common finding at operation. Falconer and Cavanagh (1959) have suggested that a small middle cranial fossa may be evidence of such lesions as mesial temporal sclerosis or glial hamartomas, and our findings bear this out. Another index of a small temporal lobe is the height of the Sylvian vessels above the floor of the middle fossa (unpublished observations), but angiography is not justified for this alone and was rarely performed in the present series.

In plain radiographs of skull, an atrophic temporal lobe may be indicated by: (1) small middle fossa floor area; (2) a relatively high petrous ridge, indicating a shallow fossa; and (3)

moderate dilatation of the temporal horns on the operated side and those who were normal radiologically.

DISCUSSION

There has been little comment in the literature concerning radiological abnormalities in tem-

thickening of temporal part of the vault and possibly excessive pneumatization.

Atrophic changes were sometimes bilateral suggesting bilateral disease. Eleven patients had unilateral abnormalities on the side opposite to the operated side. One of these had an antero-medial temporal infarct on the operated side and the radiological diagnosis was probably erroneous—the dilated horn being, in fact, within the normal range of variation. In four, there was mesial temporal sclerosis on the radiologically normal (resected) side and the outcome was good. These may have had bilateral MTS, which was epileptogenic only, or principally, on the operated side. In the remaining six cases, non-specific pathological changes were found, with a poor outcome in five (grades III and IV). In the latter it might be asked whether an operation on the radiologically abnormal side would have been more beneficial. Review of the clinical records shows, however, that the fit pattern and dominant EEG changes were on the operated side, though in all six cases there were bilateral EEG abnormalities which were often multifocal. It is probable in these cases that disease was diffuse or bilateral. It therefore seems unlikely that operation on the side of the radiological changes would have led to a better result.

The establishment of laterality of an epileptic lesion may be particularly difficult in children (Falconer, 1972). Radiological changes may prove to be a guide, but the experience of this series, which is composed mainly of adults, shows that caution is required in the case of atrophic changes. The observation of calcification or of temporal horn displacement is of greater value.

CALCIFICATION Calcified lesions are rare. Epileptogenic calcified lesions in the anterior temporal region, usually due to hamartomas, have been noted previously by several authors, including Geyelin and Penfield (1929), Alexander (1953), Falconer and Pond (1953), Kennedy and Hill (1958), Falconer and Kennedy (1961), and Falconer (1966). A calcified mass without distortion of the temporal horn was illustrated by Falconer (1970) and an instance of focal bilateral hippocampal calcification and café-au-lait spots was recorded by Williams (1972). Sometimes, calcification may direct attention to

a lesion at some distance from the electroencephalographic focus. Two cases of psychomotor epilepsy with anterior temporal spike discharges were relieved by the excision of occipital calcified lesions (Falconer *et al.*, 1962).

In this paper we report three instances of calcified hamartoma. Other cases of hamartoma showed displacement or distortion of the temporal horn, while the remainder were radiologically normal. All were benefited by surgery.

CONCLUSIONS

There would thus appear to be considerable value in such radiological studies in intractable temporal lobe epilepsy. To some extent the nature of the lesion may be predicted. Calcification, a small middle cranial fossa, and displacement of the temporal horn are the most specific changes, while the presence or absence of ventricular dilatation is less reliable since it does not distinguish MTS from non-specific gliosis unless the middle fossa is also small. In our most recent work we have used tomography of the temporal horn, as have Fredy and Bories (1972).

Considerable caution needs to be observed in the interpretation of radiological changes, particularly if the clinical and electroencephalographic pictures are at variance. The absence of radiological changes does not exclude an epileptogenic lesion with a well-defined focal histology.

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