THE INCIDENCE AND NATURE OF INTRACRANIAL CALCIFICATIONS AFTER TUBERCULOUS MENINGITIS

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Intracranial calcifications following tuberculosis of the central nervous system have until recently been rare. This is surprising considering the high incidence of intracranial tuberculomata and the frequency with which tuberculous lesions calcify in other parts of the body.

During the second half of the nineteenth century tuberculomata were considered to account for approximately half of all intracranial 'tumours' (White, 1886; Starr, 1890). Since then there has been a progressive diminution of both their absolute and relative incidence, but even in 1925 Critchley found that tuberculoma was the commonest intracranial tumour in his selected series of 125 children (no figures given). In a study of necropsy material collected in Leeds between 1910 and 1931 Garland and Armitage (1933) found that of 264 intracranial tumours 33·8% were tuberculomata. Other reports (van Wagenen, 1927; Walshe, 1931; Cushing, 1932; Stern, 1937; Zülch, 1938; Dott and Levin, 1939; Wilson, 1940), chiefly from neurological centres, put their incidence very much lower. In 1949 Walker and Hopple thought that less than 1% of all intracranial tumours in the U.S.A. were tuberculomata. In countries where tuberculosis is still very prevalent the proportion of tuberculomata among intracranial tumours is still high (Asenjo, Valladares and Fierro, 1951).

From the available data it is impossible to calculate the incidence of calcification of intracranial tuberculomata. In a partial review of the literature Scott and Graves (1933) found 11 instances among 815 cases, representing 1·35%. The rarity of calcifications may partly be due to the poor prognosis in cerebral tuberculoma and partly to absence of radiological studies.

In an extensive search of the literature of the past 100 years I was able to find 49 examples of intracranial calcifications where these were proved or believed to have been calcified tuberculomata. Thirteen of these were discovered at necropsy

(Table 1) and 36 were found on x-ray examination of the skull (Table 2). Fourteen of the latter were subsequently verified at operation or necropsy, but in the 22 others the tuberculous nature of the lesions remained conjectural. Even histological examination was not decisive in old-standing cases, as the lesions had lost the specific features of tuberculoma.

Most patients with calcified tuberculomata suffered from gross neurological lesions, had epilepsy, and many were mentally retarded. The tuberculomata were situated either in the hemispheres or in the cerebellum, but taking the small size of the cerebellum into account, tuberculomata seemed to have a predilection for this site. The calcified lesions were single or multiple, and Weens (1948) reported as many as 11 foci in one patient.

Radiologically the calcified tuberculomata are stated to have a characteristic, serrated and angular appearance (Weens, 1948; Weinberger and Grant, 1942), varying from 0·5 to several centimetres in diameter. The centre of the shadow is often less dense, because of its caseous nature. The calcification begins in the periphery of the lesions, and, as the central portion shrinks and undergoes resorption, the calcareous shell fragments, giving its characteristic appearance. Eventual ossification of the lesions is stated to be not uncommon (Camp, 1930 and 1948). Most of the previously described calcified lesions were discovered in their fully developed stage. Cushing (1932), however, observed two patients with intracranial tumours which were proved to be tuberculomata at operation and were left *in situ*. The patients recovered and eventually calcification could be demonstrated in radiographs of the skull.

Small intracranial tuberculomata may remain silent until tuberculous meningitis supervenes. As tuberculous meningitis was almost uniformly fatal until the advent of streptomycin, it is not surprising that apart from the remarkable cases of Foà (1903)

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TABLE 1
CALCIFIED TUBERCULOMATA DISCOVERED AT NECROPSY

No.	Author	Age and Sex	Clinical Features	Pathological Findings
1	Ogle (1864)	36 F	Cerebral symptoms for 1 month	Calcified tuberculoma in velum interpositum; enlarged ventricles; meningitis
2	Ogle (1864)	child	Convulsions	Calcified tuberculoma, size of hazelnut, in right cerebellum
3	Lancereaux and Lackerbauer (1871)	65 M	Right hemiparesis for 61 years	Calcified tuberculoma, size of hazelnut, in left thalamus
4	Dunlop (1893)	8 F	Headache, ataxia, right hemiparesis and blindness for 14 months. Died of tuberculosis meningitis.	Bean-sized calcified tuberculoma in right cerebellum
5	Siemon (1893)*	? ?	?	Solitary calcified and ossified tuberculoma, 4.5 × 2.5 cm., in frontal lobe
6	Foà (1903)	10 M	Recovered from 'meningitis' in infancy; died of nephritis	Hydrocephalus; calcified tuberculoma in left cerebellum
7	Stewart (1927)	23 M	Headaches; extensive tuberculosis; died of Addison's disease	Dense, hazelnut size calcified tuberculoma in right lobe of cerebellum
8	Smith (1927)	62 F	Left hemiparesis for 58 years	Stony, hard, calcified tuberculoma in right cerebral hemisphere and lenticular nucleus
9	Garland and Armitage (1933)†	50 M	—	Patchily calcified tuberculoma in left frontal lobe
10	Evans and Courville (1938)	10‡ M	Recovered from 'tuberculous meningitis' at 3 years of age; T.B. of bone; died of generalized convulsions	Calcified tuberculoma, 3 × 1.3 × 0.7 cm., in right frontal lobe; hydrocephalus; non-calcified tuberculoma in left cerebellar hemisphere
11	Evans and Courville (1938)	6 M	Listlessness and irritability for three weeks; tuberculous meningitis	Several calcified and ossified tuberculomata in both cerebral hemispheres
12	Robles (1943)‡	? ?	—	No details available
13	Lopez Clares (1944)‡	? ?	—	Calcified tuberculoma in right parietal lobe

* Reported by Ström. † Also re-described Stewart's case (No. 7). ‡ Original articles not available.

and of Evans and Courville (1938) no instances following possible tuberculous meningitis have been reported. Foà's patient, a boy of 10 years of age, was stated to have recovered from 'meningitis' in infancy, but with residual hydrocephalus. He died of nephritis. At necropsy a calcified tuberculoma was found in the cerebellum. One of Evans and Courville's patients (Case 2) appears to have suffered from 'serous tuberculous meningitis' at 3 years of age. He died seven years later of extensive tuberculosis. At necropsy there was a calcified tuberculoma in the right frontal lobe and a fresh tuberculoma in the cerebellum. Basal adhesions and hydrocephalus were evidence of an old meningitic process. Apart from a patient of my own (Lorber, 1951b) and one of Koch (1951) no intracranial calcification has yet been reported in cases of tuberculous meningitis treated with streptomycin. Indeed, calcification following any form of meningitis was stated to be of great rarity (Camp, 1948) unless the meningitis was associated with encephalitis. Levinson and Hartenstein (1951) reported massive intracranial calcification seven months after severe pneumococcal meningitis in an infant who remained deaf, blind, epileptic, severely

retarded, and had generalized rigidity. Camp (1948) found intracranial calcification in two children after polioencephalitis.

Present Investigation

The present investigation started because it appeared that there might be an appreciable incidence of intracranial calcification in patients who recovered from tuberculous meningitis. For this reason radiographs of the skull were taken on admission of each child admitted with tuberculous meningitis, and at approximately three to six month intervals in all survivors. No calcifications were found either on admission or during the course of treatment.

The material of this investigation consists of all the first 25 surviving children treated at the Children's Hospital, Sheffield, who survived from a minimum of two and a half years to a maximum of four and a half years after the onset of tuberculous meningitis. All the children are well and free from any evidence of active infection, although some have certain neurological sequelae. In addition, reference will be made to two children who died 21 and 29

TABLE 2
PROVED AND UNPROVED CALCIFIED INTRACRANIAL TUBERCULOMATA DISCOVERED DURING LIFE

No.	Author	Age and Sex	Clinical Features	X-ray Findings	Operation or Necropsy Proof	Comment
1	Klieneberger (1909-10)	12 M	Positive tuberculin; increasing headaches, vomiting, papilloedema, blindness, drowsiness, spasticity	Mass in region of corpora quadrigemina made up of 3 individual lesions	—	May have been a tumour
2	Sabat (1913)	17 ?	Left-sided convulsions for 3 years followed by permanent hemiplegia and blindness	Walnut-sized calcified mass in right hemisphere	Removal at operation, died of tuberculous meningitis few days later	—
3	Ström (1919-21)	21 F	Convulsions of increasing frequency for 12 years; right-sided hemiparesis	Calcified mass, 3.5 × 3 cm., in left frontal lobe	Removed at operation; died next day. Histology, calcified and partly ossified mass	No specific tissue detected on histological examination
4	Kingreen (1924)	10 M	—	Two calcified shadows in hemispheres	One removed at operation; died 4 days later. Second lesion at necropsy had tuberculous granulation tissue	—
5	Sauer (1928)	7 M	Convulsions for 5 years; hemiplegia (right); tuberculin positive	Five calcified shadows, all on left side	—	—
6	Cushing (1927)	14 M	Signs of increased intracranial pressure thought to be due to cerebral tumour	Progressive intracranial calcification	Exploratory operation; tuberculoma found and left <i>in situ</i>	See text
7	Cushing (1932)	? ?				
8	Paterson and Stevenson (1930)	16 M	Convulsions	Solitary calcified mass in right parietal lobe	Removal at operation; central caseous mass	Survived
9	Puusepp and Ziaff (1933)	24 F	Ataxia and blindness for 3½ years	Calcified mass right occipital area	Removed at operation. 'Proved tuberculoma'	—
10	Puusepp and Ziaff (1933)	18 F	Ataxia and later quadriplegia for 10 years	Midline calcified mass in region of hypothalamus	Proved at necropsy	
11	Puusepp and Ziaff (1933)	29 F	Headaches, convulsions, blindness for 8 years	Calcified shadow size of hen's egg in right temporal lobe	—	
12	Vincent <i>et al.</i> (1933)	7 M	Convulsions from 15/12 of age	Calcified shadow, size of hazelnut in right parieto-occipital region	Removed 1 year later, histological proof; alive 23/12 after operation	See text
13	Borchardt (1933)	6 M	Cerebral symptoms for 4½ years; admitted with meningitis and died	Four calcified shadows	Histological proof at necropsy	
14	Coenen (1937)	19 M	Bony tuberculosis in childhood; convulsions for years	Calcified shadow in right occipital lobe	Calcified amorphous mass, 5.5 × 4.5 × 4.0 cm., removed at operation	—
15-21	Martin (1937)	Adults	All patients had convulsions and past history or present evidence of tuberculosis elsewhere in body	One to several dense calcified shadows, almost all above the tentorium	One lesion removed in Case 3 and found to be amorphous calcified mass	

months after the onset of meningitis. The treatment of these children was described elsewhere (Illingworth and Lorber, 1951).

Intracranial calcifications were radiologically demonstrated in 17 of the 25 surviving children. The length of observation from the beginning of the treatment of meningitis is shown in Table 3. In many children it was possible to observe the evolution of these calcifications, but sometimes early traces of calcifications were only detected in retrospect. In other cases shadows suggestive of early calcifications did not develop into significant lesions.

No calcifications were detected in any patient in less than 18 months from the beginning of treatment (Table 4). In 13 of the 17 the calcifications were discovered between two and three years after the onset of meningitis. In the eight negative cases the latest radiograph of the skull was taken between 29 and 50 months from the beginning of treatment and in five of these after the thirty-ninth month.

The lesions are divided into three different types according to the situation and appearance of the calcified shadows. More than one type of lesion was seen in three children, including two in whom

TABLE 2—continued.

No.	Author	Age and Sex	Clinical Features	X-ray Findings	Operation or Necropsy Proof	Comment
22	Evans and Courville (1938)	8 M	Increasing headaches for 5 years, aphasia, left hemiplegia	Calcified mass, 6×7.5 cm., in right parieto-occipital region	Histological proof at necropsy	
23	Bailey (1938)	7 M	Convulsions, tuberculin-positive, primary abdominal tuberculosis	Calcified shadow left posterior parietal region	—	
24	Pancoast <i>et al.</i> (1940)	28 M	Attacks of dizziness from age 7 to 21 years, followed by headaches	Large solitary calcified mass to the left and in front of pineal	Could not be found at operation	
25	Pancoast <i>et al.</i> (1940)	15 M	Pulmonary tuberculosis; no details given	Several calcified shadows	—	
26	Camerer (1940)	10 F	Primary tuberculosis	Bean-sized calcified lesion behind and above the sella	Proved at necropsy	
27	Camerer (1940)	10 M	Primary tuberculosis of lung at 3½, papilloedema, headache; normal C.S.F.; quadriplegia; negative skull radiograph; remained an idiot	Incipient calcification in posterior fossa at 4½. At 10 years, large plum-sized mass in posterior fossa	—	
28	Weinberger and Grant (1942)	12 M	Convulsions and left hemiplegia; healed primary pulmonary T.B.	Calcified shadow right parieto-occipital region	Removed at age of 15; histological proof	
29, 30	Penfield and Ward (1948)	? ?	Epilepsy; no details given	?	—	Very doubtful; no evidence given
31	Weens (1948)	1½ F	Accidental discovery in tuberculous infant without cerebral symptoms who died of T.B.M. at 3	Several calcified shadows in all areas	Eleven calcified tuberculomata found, some with active caseation	See text
32	Weens (1948)	1½ M	Primary tuberculosis of lung; tuberculosis of rib and mandible	Four calcified shadows	Died ? cause; no necropsy	
33	Weens (1948)	9 M	Known T.B. from age of 1 year; convulsions at 3 and 5; healthy later; accidental discovery after head injury	Serrated, oval calcified shadow, 7×10 mm., in right parieto-occipital region	—	
34, 35	De Sa (1949)	? ?	No data given	Calcification in two cases	One 'confirmed' at operation	Doubtful cases; no evidence given
36	Koch (1951)	3 M	Tuberculous meningitis treated with streptomycin; residual left hemiplegia 14/12 after onset	Extensive calcifications in right parietal region found at encephalography	—	See text

calcification of the falx cerebri was detected. As calcification of the falx is common under physiological conditions in adults over 30 years of age (Camp, 1930), it may not necessarily be pathological in children. For this reason these calcifications will not be further considered.

In eight children calcified lesions were seen which were situated apparently within the brain substance (Figs. 1 and 2). In seven of the eight a solitary intracerebral calcified shadow was found, but in a previously reported case two shadows were

TABLE 3

INTRACRANIAL CALCIFICATIONS IN RELATION TO THE LENGTH OF OBSERVATION*

Length of Observation (years)	Total Number of Cases	Number with Calcifications
4—4½	6	4
3½—4	5	4
3—3½	5	3
2½—3	9	6
2½—4½	25	17

* Survivors only.

TABLE 4

FIRST APPEARANCE OF CALCIFICATION FROM BEGINNING OF TREATMENT IN 17 PATIENTS

Period	Number
Up to 18 months	0
19—24 "	3
25—30 "	6
31—36 "	7
37—42 "	1
Over 42 "	0

FIGS. 1 and 1a.—Small calcified shadow, ? in the parietal lobe of the brain first seen 29 months after onset of meningitis; grew in size and density during next 15 months (Case 10).

FIGS. 3 and 3a.—Basal calcification above and behind sella first noticed 31 months after onset of meningitis. It increased in size subsequently (Case 12).

FIGS. 2 and 2a.—Cluster of intracerebral calcifications apparently in occipital lobe. First seen 36 months after onset of meningitis; became denser in next 12 months (Case 6).

FIGS. 4 and 4a.—Plaque-like basal calcification above sella faintly seen 36 months after onset of meningitis; much denser and longer in next 12 months (Case 5).

FIGS. 5 and 5a and 6 and 6a.—Showing increasing size and density of massive calcifications just above sella, presumably in cisterna ambiens, and a second group of calcifications further back in area of mid-brain. First faint signs 19 months after admission. Fig. 5 represents the condition, 36, and Fig. 6, 43 months after admission (Case 8).

present (Lorber, 1951b). Most of these calcifications were small, with a diameter of a few millimetres (Fig. 1). The bigger shadows in the present series were composed of clusters of numerous small calcified foci (Fig. 2).

In 11 children more spectacular and less expected calcified shadows were found at the base of the brain.

These calcifications were either immediately above or above and behind the sella (Figs. 3-6). Most were of plaque-like appearance, straight, curved or branching shadows (Figs. 3-4). These, too, were composed of clusters of smaller, individual shadows. In other cases much bigger, conglomerate masses of calcifications were seen (Figs. 5 and 6). They were easily demonstrable on lateral radiographs of the skull, but because of their position at the base they were hidden by the paranasal sinuses and other structures of the face on the antero-posterior view. Towne views and stereoscopic lateral radiographs showed that these calcifications were either in or very near to the midline, in the approximate situation of the main basal subarachnoid cisterns. The site and incidence of these calcifications corresponded closely both with the site and the incidence of

tentorial obstructions, which were demonstrated by encephalography. In encephalograms a large air bubble is seen to be held up just above the sella, in the cisterna ambiens and other basal cisterns (Fig. 7) and it is just here that these plaques or

FIG. 7.—Encephalogram in a case of tuberculous meningitis showing block at the tentorial opening. Note large collection of air in the basal cisterns.

clusters of basal calcification develop. Their position also corresponds well with the site of the most dense exudate found at necropsy in fatal cases of tuberculous meningitis.

There was a much higher incidence of calcifications (Table 5) in patients who were in the

TABLE 5
INTRACRANIAL CALCIFICATIONS IN RELATION TO STAGE OF MENINGITIS ON ADMISSION

Stage of Disease	Total No. of Patients	Patients with Calcification		
		Basal	Cerebral	Total
Early*	10	0	4	4
Intermediate	11	9†	3†	10
Advanced	4	2	1	3
Total	25	11†	8†	17

* Including five patients who developed meningitis while being treated for miliary tuberculosis.

† Includes two patients with both basal and cerebral calcifications.

intermediate or advanced stage of meningitis (13 of 15) than in those who were in the early stage (four of 10). If intracerebral calcifications alone were taken into account, then no significant difference was found between patients in the three stages. If, however, only the basal calcifications

were considered, then the differences were striking. No basal calcifications were seen in any of the 10 early cases, but they were detected in 11 of the 15 children in the intermediate and advanced stages. This observation again corresponds well with encephalographic studies (Lorber, 1951a) in which it was shown that in early cases obstruction of the cerebrospinal fluid pathways and tentorial blocks only rarely develop, whereas they may be found in over half of the intermediate and in almost all the advanced cases. In this connexion it is of interest that one of our patients in the early stage of meningitis recovered but later died of tuberculous bronchopneumonia. In this patient no basal exudate was found at necropsy.

There was only slight correlation between intracranial calcifications and the presence of neurological sequelae. Excluding deafness in two children, which may have been due to streptomycin, six of the 25 patients had physical or mental lesions. Intracranial calcifications were found in three of four who had hemiplegia, and in one of the other children with residual abnormality. Of the 19 patients who made a complete functional recovery only 12 developed intracranial calcifications. The basic data patients are presented in Table 6.

TABLE 6
BASIC DATA RELATING TO 25 PATIENTS IN THE PRESENT INVESTIGATION*

No.	Sex	Age on Admission	Stage of Disease† on Admission	On March 30, 1952		First Appearance of Intracranial Calcification (months after admission)	Site and Type of Intracranial Calcification
				Length of Observation (months)	Sequelae		
1	M	6½	I	54	None	27	(1) In frontal lobe; (2) basal, above sella
2	F	5½	E	51	None	—	—
3	M	15/12	E†	53	None	—	—
4	F	6	I	50	Deaf	35	Basal, behind sella
5	M	3	I	48	None	36	Basal, above sella (Fig. 4)
6	M	11/12	E†	48	None	36	In occipital lobe (Fig. 2)
7	F	8	E†	47	None	34	In parietal lobe
8	F	5½	I	46	None	19	(1) In area of midbrain (Figs. 5 and 6); (2) massive basal (?cisterna ambiens); (3) falx
9	F	16/12	E†	46	Deaf	—	—
10	F	8	I	44	None	29	In ?parietal lobe (Fig. 1)
11	M	20/12	A	43	Moderately retarded	42	(1) Basal, behind and above sella; (2) falx
12	F	7½	I	42	None	31	Basal, above and behind sella (Fig. 3)
13	M	13/12	A	41	Hemiplegia; retardation	—	—
14	F	10	I	40	None	—	—
15	F	20/12	I	40	None	27	Basal, behind sella
16	M	9	E	36	None	27	In frontal lobe
17	M	2	I	34	Hemiplegia; retardation; Fits	32	Massive basal, above sella
18	F	5½	A	34	Sexual precocity; optic atrophy	19	Two in parietal lobe (Lorber, 1951b)
19	M	10/12	E	34	None	—	—
20	F	19/12	E†	33	None	—	—
21	M	3½	I	33	Hemiplegia	32	Basal, above sella
22	M	12	I	31	None	27	Basal, behind sella
23	F	4½	E	31	None	—	—
24	F	3½	A	30	Hemiplegia	29	Basal, above sella
25	F	3½	E	30	None	19	In frontal lobe

* Survivors only.

† Patients who developed meningitis while on treatment for miliary tuberculosis. E=early. I=intermediate. A=advanced.

In our series of well over 100 cases of tuberculous meningitis treated with streptomycin all but two of the deaths took place in less than 18 months from the beginning of treatment. In the last two children calcified lesions were detected in the central nervous system at necropsy. On one child, who died 21 months after the beginning of treatment, a post-mortem radiograph of the brain showed some faint flecks of possible calcification in the region of the temporal lobe. These could not be located on slicing the brain. In the spinal canal, however, the meninges, and particularly the dura, were found to be calcified, and even ossified (Figs. 8 and 9).

series, however, is such that it leaves little doubt that there must be a causal relationship between tuberculous meningitis and subsequent intracranial calcifications. For this reason it is unnecessary to discuss the differential diagnosis of pathological intracranial calcifications. Intracranial calcifications occur in normal persons in the choroid plexus, the pineal body, the tentorium cerebelli and the petro-clinoid ligaments, but none of these sites was affected in the present series.

Assuming that these calcifications are a sequel to tuberculous meningitis, there are four possible causes to consider. They may represent calcified

FIGS. 8 and 9.—Sections of the spinal cord showing calcification and ossification of the meninges between the nerve roots.

The second late death occurred in a child 29 months after the beginning of treatment. Faint suspicion of calcification was detected on a radiograph of the skull five months before she died. A post-mortem radiograph of the brain showed a characteristic calcified shadow in the left temporal lobe. This was subsequently located by further radiographs of the brain slices and was found to be within the brain adjacent to the Sylvian fissure. Histologically it was composed of clusters of small calcified foci, but no tuberculous granulation tissue could be detected at the same site.

Discussion

The pathogenesis and the nature of the calcified shadows require consideration. Admittedly, in none of the living patients is absolute evidence available that these calcifications occurred in tuberculous lesions. The composition of this

intracranial tuberculomata, calcification in areas of healed tuberculous encephalitis or in areas of encephalomalacia following cerebral infarction, or in the tuberculous exudate in the meninges.

The eight intracerebral lesions which have been described in the survivors are probably calcified intracranial tuberculomata. Their size and situation correspond well with the description of the 'Rich foci' and are quite unlike the more diffuse calcifications which occur after encephalitis or encephalomalacia. Eight living children with this type of intracranial calcifications are in perfect physical and mental health and for this reason alone it appears unlikely that the calcifications occurred in areas of encephalomalacia or past encephalitis. The approximately equal incidence of these intracerebral lesions in patients in different stages of meningitis at their admission favours the theory that these were the original 'Rich foci' responsible for the meningeal dissemination.

The striking collection of calcifications in the anatomical situation of the basal cisterns in 11 patients leaves little doubt that in these we are dealing with a calcifying organizing exudate of the meninges. Their situation and shape corresponds exactly to the site of the maximal meningeal inflammation. It is also striking that in patients in the early stage of the disease on admission, and in whom only minimal exudate is to be expected, no basal intracranial calcifications developed. In those in the intermediate and advanced stages, and therefore with more basal exudate, subsequent calcifications were almost the rule. The calcification and ossification of the spinal meninges in one child who died after a protracted illness demonstrated histologically that meningeal calcification is possible after tuberculous meningitis.

Areas of extensive encephalomalacia are frequently found in fatal cases of tuberculous meningitis, but in this group of 25 survivors the only patients who are likely to have such encephalomalacia are the four with residual hemiparesis. Calcifications were detected in three, but in all three these were basal. It seems, therefore, that calcifications in areas of encephalomalacia did not occur in patients in the survivors of the present series, but probably did so in Koch's (1951) patient, who had hemiplegia on the opposite side of the body. The calcifications found at necropsy in the child who died after 29 months of treatment probably also represent calcifications in a previously infarcted area.

The only remaining problem to be considered is the prognostic significance of calcifications following tuberculous meningitis. In a very large series of 548 cases of tuberculous meningitis, treated at various centres with streptomycin, only one patient died of tuberculous meningitis more than two years after the onset of meningitis (Lorber, to be published). It would be tempting, therefore, to ascribe this favourable late prognosis to the calcification of lesions which might otherwise presumably act as potential foci of reinfection of the meninges. Such an explanation, however, is unlikely to be true. Cases have been described where calcified tuberculomata were present at the time of the onset of tuberculous meningitis and in others calcified tuberculomata were discovered long before the onset of fatal tuberculous meningitis (Tables 1 and 2). Further, the radiological demonstration of one or more calcified tuberculomata does not exclude the presence of other, non-calcified lesions, nor does it exclude the presence of caseous material in the calcifying lesions.

To conclude, it is estimated that in England alone

approximately 300-400 patients are now cured annually of tuberculous meningitis. Should intracranial calcifications eventually develop in approximately two-thirds of these then tuberculosis may soon become one of the commonest causes of intracranial calcifications.

Summary

In a series of 25 consecutive children who have recovered from tuberculous meningitis and have been observed for two and a half to four and a half years 17 developed radiologically demonstrable intracranial calcifications. Most of these calcifications (13 of 17) were detected between two and three years after the onset of meningitis.

In eight the calcified foci seemed to be within the brain substance, and these were found in approximately even proportion in children in various stages of meningitis at the beginning of their treatment.

In 11 children plaques or clusters of calcification developed in the anatomical situation of the basal subarachnoid cisterns. These are considered to be calcifications in the meningeal exudate at the base of the brain. They were not found in any of the 10 children who were in the early stage of the meningitis on admission, but were present in 11 of the 15 who were in the intermediate or advanced stage.

No definite correlation was found between the incidence of intracranial calcifications and the presence of neurological sequelae.

In one child, who died of tuberculous meningitis after 21 months of treatment, calcification and ossification of the spinal meninges were found at necropsy. In an other child, who died 29 months after the beginning of treatment, a calcified intracerebral focus was found at necropsy.

The nature and pathogenesis of the calcified lesions are considered.

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Addendum

At the time of correcting the proofs of this paper basal intracranial calcifications were detected in one more child within this series (Case 13—an advanced case) 47 months after his admission. Thus all four patients with hemiplegia showed calcified intracranial shadows.

There has been no significant change in the other patients and the period of observation now ranges from a minimum of 38 months to a maximum of 62 months from the beginning of treatment.