Brain abscess

Review of 89 cases over a period of 30 years

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SUMMARY Eighty-nine cases of brain abscess, diagnosed over a period of 30 years, are reviewed. The incidence of this disease did not decline throughout the period. Abscesses of ear and nose origin constituted the largest group (38%). Postoperative abscesses seem to have increased in incidence, presumably due to routine postoperative antibiotic treatment. Antibiotics were possibly responsible for the suppression of signs of infection in 45% of the patients, who presented as suffering from a space-occupying lesion. The most accurate diagnostic tool was angiography, which localized the lesion in 90% and suggested its nature in 61%. Brain scan may prove as satisfactory. *Staphylococcus* was cultured in about two-thirds of the cases. Mortality seemed to decrease concomitantly with the advent of more potent antibiotics. The treatment of choice in terms of both mortality and morbidity seemed to be enucleation after previous sterilization. The hazards of radical surgery should be taken into consideration.

The multiplicity of factors involved in the management of brain abscess complicates its evaluation. Surgical therapy in the pre-antibiotic era carried a mortality of 61% (Webster and Gurdjian, 1950). The use of antimicrobials and antibiotics improved the prognosis (Jooma, Pennybacker, and Tutton, 1951) but the high hopes expressed with the advent of these agents were not realized. The improvement in morbidity and mortality since the use of antibiotics did not continue (Gregory, Messner, and Zinneman, 1967) and the incidence of brain abscess did not decrease (Garfield, 1969). This disturbingly meagre progress necessitated the reassessment of our own methods of treatment and the reevaluation of the variables involved. To this end the records of patients with brain abscess admitted to our department during the last 30 years were reviewed. This period covered the three stages of antimicrobial therapy and coincided with the development of the neurosurgical service in the hospital.

A total of 89 cases was studied. In all cases the presence of pus within the brain substance was verified either at operation or at necropsy. Cases with localized bacterial encephalitis and epidural

or subdural collections of pus were not included in this study.

FINDINGS AND COMMENTS

INCIDENCE The yearly incidence varied between one and 10 patients per annum, with no apparent change among the three decades (Fig. 1). One has, however, to take into consideration the fact that the total number of beds in the hospital did not change in this period. On the other hand, during the first eight years of the study period, ours was the only neurosurgical service in Israel. Although the population trebled during the period under study, there are now six neurosurgical services in our country. Taking into account all these factors, it may be assumed that the true incidence of brain abscess increased during this period of 30 years.

A preponderance of males over females (60:29) was found among our patients.

The age distribution is presented in Fig. 2. The highest incidence was among infants—15%. The 38 cases in children under the age of 15 constituted 43% of all cases. The youngest patient was 2 months old, the oldest 70 years. The pre-

FIG. 1. Yearly incidence of brain abscess. No apparent change in incidence over the three decades. Shaded column: females. Open column: males.

FIG. 2. Age distribution of brain abscess. Note the high incidence among infants.

dilation of the disease for children may be partly explained by the greater prevalence of paracranial and particularly ear infections in this age group. This may give rise to brain abscess by contiguous spread. The four cases associated with congenital heart disease also occurred in childhood. In the older age groups there were no significant variations in incidence.

SOURCE OF INFECTION In 51 cases the source of infection was within or near the cranial cavity (Table 1). The ear and nose infections constituted the largest group—38% of all cases.

Twenty-four per cent of all the abscesses were considered to be secondary to a focus of infection harboured in other parts of the body. In 19% the primary site of infection could not be established. It is noteworthy that no differences in relative incidence were found in either of the above-mentioned groups between the sulphonamide and antibiotic eras. However the incidence of postoperative brain abscesses and those with a distant primary focus were strikingly higher in the antibiotic era. This may be attributed to the frequent and indiscriminate use of antibiotics in unlocalized infection and its preventative use

TABLE 1
SOURCE OF INFECTION

	1940-50	1940-71
I a. Ear and mastoid	7	27
b. Paranasal sinuses	1	7
c. Postoperative	1	10
d. Post-traumatic	4	7
	13	51
II a. Pulmonary	2	5
b. Paradoxical	2	4
c. Distant metastatic	1	12
	5	21
III Unknown	5	17
	23	89

after surgery. Many of the antibiotic drugs are only bacteriostatic, thus the infection may be temporarily subdued and flare up after a dormant period. The following is illustrative of such complication.

A 22 year old female was admitted in 1951 with an 11 year history of episodes of tachycardia accompanied by the 'feeling' of an unpleasant smell and sometimes followed by loss of consciousness. The sole neurological finding was a right lower quadrant homonymous anopia. Radiographs of the skull showed calcification in the left temporal region. At craniotomy a dermoid cyst was removed from the floor of the left middle fossa. The patient was given routine antibiotic treatment postoperatively and recovery was complete. Six months later the patient was re-admitted because of right-sided Jacksonian seizures. Several days later a fever of 40° C developed, together with signs of increased intracranial pressure. On lumbar puncture the cerebrospinal fluid (CSF) was purulent and grew *Staphylococcus aureus*. At repeated craniotomy a thick-walled abscess was enucleated from the site of the previous lesion. The patient made an uneventful recovery.

Four cases of the so-called 'paradoxical' brain abscess were included in this series. All these patients suffered from congenital heart disease which resulted in an arteriovenous shunt. It is assumed (Wechsler and Kaplan, 1940) that infected emboli during transient bacteraemia bypassed the pulmonary capillaries and reached the greater circulation and thus the brain via the congenital heart defect. Before the antimicrobial era this type of brain abscess was diagnosed only at necropsy (Beller, 1951). Since the late '40s the

number of successfully treated 'paradoxical' abscesses has grown steadily. It should, however, be kept in mind that, unless the cardiac defect is repaired, the route for repeated infection remains open. This is illustrated in the following case.

In 1948 a 6 year old boy with tetralogy of Fallot had a chronic abscess removed from the left parietal lobe. The child recovered completely. Repair of the cardiac disease was not considered feasible. In 1958 the boy was admitted again with signs of a right frontal lobe space-occupying lesion. An abscess was diagnosed and evacuated by repeated aspirations. He again made a complete recovery. He was admitted for the third time in 1966 because of headaches and right-sided Jacksonian seizures. Only angiography revealed a left temporal avascular space-occupying lesion. Pus was evacuated by repeated aspirations. The patient's recovery was again complete.

SITE OF SUPPURATION The abscesses were divided equally between the right and left halves

TABLE 2
SITE OF BRAIN ABSCESES

	Right	Left	Total
Frontal	11	10	21
Parietal	6	9	15
Temporal	14	16	30
Occipital	6	4	10
Cerebellar	8	5	13
	45	44	89

TABLE 3
SITE OF 34 OTOGENIC AND RHINOGENIC ABSCESES

	Frontal	Temporal	Parietal	Cerebellar
Otitis				
ipsilateral	1	11		5
unilateral		2		
contralateral	1	1	2	4
bilateral				
	2	14	2	9
Frontal sinusitis	4			
Maxillary sinusitis		2		
Pansinusitis	1			
	5	2		

of the brain (Table 2). The lobes affected most frequently were the temporal and frontal. The data presented in Table 3 further stress the role of otogenic and rhinogenic infections as sources of brain abscess. The site of the abscess was ipsilateral or adjacent to the infected ear or sinus in 32 out of 34 cases. This also suggests a contiguous type of spread. In the remaining two cases it is possible that otitis had previously been bilateral and had 'healed' by antibiotic treatment. The intracranial complication became manifest in spite of disappearance of signs of infection at the source.

BACTERIOLOGY Table 4 lists the types of bacteria found in the abscesses in this series. A total

TABLE 4
TYPES OF ORGANISM CULTURED

<i>Staph. aureus</i>	24	} 45 monobacterial
<i>Staph. albus</i>	1	
<i>Strep. haemolytic</i>	4	
<i>Strep. anhaemolytic</i>	3	
<i>Proteus</i>	4	
<i>Pseudomonas</i>	4	
<i>Meningococcus</i>	1	
<i>Haemophilus</i>	1	
<i>Bacteroides</i>	2	
<i>Pneumococcus</i>	1	
<i>Staph. and proteus</i>	4	} 12 polybacterial
<i>Staph. and strep.</i>	2	
<i>Staph. and Esch. coli</i>	1	
<i>Proteus and pyocyanus</i>	2	
<i>Strep. and Esch. coli</i>	2	
<i>Strep. and proteus</i>	1	
<i>Pseudomonas and klebsiella</i>	1	
Sterile	17	
	74	
No culture	15	

of 74 cultures were obtained. Of these 45 grew a single type of organism and in 12 more than one type was found. *Staphylococcus* was by far the commonest organism cultured (see Table 9); it was found in 63% of the positive cultures. The second largest group were streptococci, found in almost 20% of the positive cultures. Both these types of gram-positive cocci were evenly distributed throughout the period under study.

The 17 cases in which culture of the pus yielded no growth were also evenly distributed during the period. The 'sterilization' of the pus is probably caused by preoperative antimicrobial or antibiotic treatment, again, not eradicating infection but rendering it sterile for *in vitro* growth.

CLINICAL FEATURES Of the 89 patients, 82 were first diagnosed during life and treated. The most prominent symptoms and signs were headache, focal neurological signs, either irritative or deficit, and an altered state of consciousness. Forty of the patients presented with no symptoms or signs of an infective process (Table 5) and therefore were diagnosed at first as suffering from a space-occupying lesion. It should be

TABLE 5
SYMPTOMATOLOGY OF BRAIN ABSCESSES

	Neurological syndrome only	Neurological and signs of infection
1941-46	5	7
1948-53	8	18
1954-59	8	14
1960-65	13	6
1966-71	6	4
	40	49

TABLE 6
EEG FINDINGS

Focal disturbance	14
Regional disturbance	17
Hemispheric disturbance	4
Signs of increased pressure only	2
Diffuse disturbance	5
Normal	3*

* Two cases—cerebellar abscess.

noted that during the last decade of the study there was a rise in the relative incidence of the 'non-infective' cases. Such modification of the clinical features may be attributed to the use of antibiotics before admission.

Sixteen patients were admitted with sudden onset of meningitis due to rupture of the abscess.

FIG. 3. Serial brain sections showing extensive non-capsulated abscess. The patient had received steroids.

into the cerebrospinal fluid system. Their clinical course was in no way different from that of the other patients.

When dealing with the clinical picture of brain abscess, mention should be made of treatment with steroids. Four of our patients had had steroid treatment before their admission to our department. Only one of these survived. Steroids probably increase the hazards of local and general infection and mask its clinical manifestations. Moreover, they seem to prevent the local limitation of the inflammatory process by capsule formation. The following case helps to illustrate this.

A 14 year old girl was treated by dilatations for caustic constriction of the oesophagus. To prevent excessive scarring she was also given steroids and 'preventive' antibiotics. One week before admission

to our department she complained of headaches and a neurologist found papilloedema with minimal pyramidal signs on the right. There were no systemic signs of infection. On the day of transfer to neurosurgery the girl suddenly lapsed into coma and Cheyne-Stokes respiration, followed by hypotension. She died shortly afterwards. At necropsy an abscess which had destroyed a large part of the left hemisphere was found (Fig. 3).

The other two fatal cases had also extensive supratentorial noncapsulated abscesses. They died with signs of acute brain-stem compression.

METHODS OF LOCALIZATION An electroencephalographic (EEG) examination was performed in 45 of the treated patients (Table 6). It showed the focal disturbance considered typical for brain abscess (Kiloh and Osselton, 1961) in only 14

FIG. 4. Right carotid angiogram demonstrating a large temporal avascular space-occupying lesion. This finding but not the symptoms or signs suggested the presence of pus.

cases. In 17 additional cases this examination was useful in localizing the process and choice of the next diagnostic procedure. These efficacy rates of the EEG are in agreement with Garfield's (1969) data.

In 15 cases, most of them in the earlier years, the pus was located by direct puncture. In two of these, pus was aspirated during an attempt at ventriculography. In an additional three cases the site of a previous operation was punctured or re-explored (Table 7).

TABLE 7
METHODS OF LOCALIZATION OF BRAIN ABSCESES

	Angiography		Ventriculo-graphy	Pneumo-encephalo-graphy	Direct puncture
	Site	Nature			
Studies (no.)	31	19	21	16	15†
Equivocal or negative	3*		4	6	3
Accuracy (%)	90	61	81	63	83

* One cerebellar abscess.
† In three cases the site of previous operation was punctured or re-explored. In two additional cases pus was aspirated at attempting ventriculography.

Sixteen patients were studied by pneumoencephalography; none of them had signs of increased intracranial pressure or infection. This procedure was the least effective for diagnosis and also frequently resulted in rapid aggravation of the patient's condition. Less frequent deterioration was observed during or after ventriculography, which was accurate in 81%. It is possible that complications of ventriculography were less appreciated, since in our practice it immediately precedes definitive surgery.

Angiography seemed to be the most accurate and also the safest procedure. It helped localize the process in 90% of the cases in which it was performed. Moreover, by demonstrating an avascular process it suggested its correct nature in 61%. The accuracy of this procedure, mainly from this aspect, increased with the gain of experience and with multiphase angiography.

FIG. 5. ⁹⁹Tc brain scan. Note the area of uptake which is triangular on anteroposterior view and ring shaped on lateral view. The burr-hole was placed above the centre of the ring.

The importance of preoperative suspicion of the presence of intracerebral pus need not be stressed (Fig. 4).

Brain scan with ^{99}Tc was performed in four cases and was positive in all. In one case (Fig. 5), due to the ring shape of the lesion, this study was considered sufficient, as it proved to be. This examination seems to be the least hazardous and promises a high degree of accuracy with further experience. It may also help identify multiple lesions (Tefft, Matson, and Neuhauser, 1966).

MORTALITY Eighty-two of the 89 patients had surgical treatment. The seven patients who died before surgery had been ill with other diseases which were complicated by brain abscess. When the complication was recognized the patient was moribund and the diagnosis was made at necropsy. Thus the overall mortality of treated brain abscess was 40%. It seemed to decrease in the last five year period.

The basic factors influencing mortality are reviewed below.

Age No significant correlation was found between the age of the patient and mortality. This was true even in infants (Table 8). This agrees with findings of others (Dawes, 1961; Garfield, 1969).

TABLE 8

AGE DISTRIBUTION OF MORTALITY (TREATED CASES ONLY)

Age (yr)	Cases (no.)	Deaths (no.)	Mortality (%)
0-2	12 (13)*	4	33
3-5	8 (9)	3	38
6-10	9 (9)	3	33
11-15	6 (7)	2	33
16-20	5 (5)	2	40
21-40	20 (23)	9	45
41-55	13 (14)	7	54
56-70	9 (9)	3	33
All treated cases	82	33	40

* Figures in parentheses represent total numbers of patients.

Bacteriology From Table 9 it appears that staphylococci caused the largest number of deaths. They also constituted the largest group

TABLE 9
MORTALITY ACCORDING TO ORGANISM

Organism	Cases (no.)	Deaths (no.)	Mortality (%)
Staphylococcus	25	10	40
Staph. and other bacteria	7	3	43
Total no. of staph.	32	13	41
Streptococcus	7	1	14
Strep. and other bacteria	3	3	100
Other bacteria	15	6	40
Sterile culture	17	7	41
Total*	74	30	41

* In additional 15 cases cultures were not obtained.

and the mortality rate did not differ from the average. There seemed to be a low death rate in abscesses produced by streptococci in mono-bacterial growth. This is contrary to other observations (Gregory *et al.*, 1967; Garfield, 1969). The virulence of other organisms is difficult to assess due to the small numbers. The question as to whether polybacterial growth carries a higher mortality is difficult to answer. It seems that the prognosis in such abscesses depends on the most virulent of the several organisms.

Sterile cultures did not carry any better prognosis. This suggests only that *in vitro* sterility bears little or no relation to *in vivo* virulence (Sperl, MacCarty, and Wellman, 1959). 'No growth' could be the result of preoperative antibiotics (Ballantine and Shealy, 1959) or anaerobic or slow growing organisms (Liske and Weikers, 1964; Salibi, 1964).

Arranging the cases by periods (Table 10) there seemed to be a drop in mortality in the years 1951-55 and again since 1966. These periods coincide with the more extensive use of penicillin and later with that of broad spectrum antibiotics. In the latter period more potent drugs such as the synthetic penicillins and garamycin became available.

Rupture of abscess This is considered one of the most feared sequelae of brain abscess. It was the most frequent cause of death in several reports (Lewin, 1955; Ballantine and Shealy, 1959). In

TABLE 10
MORTALITY FROM BRAIN ABSCESS

Period	All cases		Treated cases	
	(no.)	(%)	(no.)	(%)
1941-45	7	58	6	54
1946-50	5	45	5	45
1951-55	6	33	5	28
1956-60	13	65	8	40
1961-65	7	39	7	39
1966-71	2	20	2	20
Total	40	45	33	40

our series, however, it occurred only eight times—10% of all treated cases. Rupture of the abscess was fatal in five cases or 15% of all post-operative deaths. In four of these the rupture was into the 4th ventricle. The rupture of a supratentorial abscess, therefore, should not be considered as an ominous sign.

Multiplicity Eight of the patients had either multilocular or multiple abscesses. Five of these died—a mortality of 63%. Two of the survivors had multiloculated interconnecting abscesses which were enucleated. One patient had three paradoxical abscesses on three separate occasions.

CAUSES OF DEATH Table 11 lists the causes of death in the surgically treated cases. Uncontrolled infection seemed to be the major cause of death accounting for 16 out of the 33 fatalities. In the last decade however, this occurred in only three cases—no doubt due to the use of more potent antibiotic agents.

TABLE 11
CAUSES OF POSTOPERATIVE DEATH

	1941-45	1941-71
Meningitis/ventriculitis	4	14
Rupture into 4th ventricle	1	4
Multilocular/multiple abscess		5
Acute herniation	1	4
Septicaemia		2
Congestive heart failure		2
Other		2
Total	6	33

Acute temporal or brain-stem herniation was encountered in four postoperative cases and in all the seven who died before coming to surgery. Urea and mannitol administration or emergency surgery were of limited help (Pennybacker, 1961). Four additional cases with rupture of cerebellar abscess into the 4th ventricle, died probably from direct and acute compression of the brain-stem. Death due to failure to recognize and localize all lesions in multiple abscesses led to death in five cases (Tutton, 1953).

METHODS OF SURGICAL TREATMENT During most of the reviewed period treatment was supervised by one person (A.J.B.). The choice of the surgical treatment was based on the current neurosurgical thought, the preoperative diagnosis, and the patient's condition. In the early period drainage was mainly performed (Table 12).

TABLE 12
ASSESSMENT OF SURGICAL PROCEDURE

Procedure	Cases (no.)	Survivals	Deaths	Mortality (%)
Drainage	6	4	2	33
Aspiration	33	16	17	52
Primary resection	26	17	9	35
Aspirations and resection	17	12	5	30
Total treated	82	49	33	40
untreated	7		7	100
Total no. of cases	89	49	40	45

12). As its dangers became apparent (King and Turney, 1954) treatment by repeated aspirations was preferred. After aspiration the abscess cavity was irrigated with an antibiotic solution and then iophendylate (Pantopaque) together with air were introduced. Changes in the size of the cavity on radiography indicated the need for further aspirations (Fig. 6). Resection was performed either as the primary procedure or after repeated aspirations. Primary resection was attempted when the abscess was located in a 'silent' area, when there was reason to believe that a chronic wall was present, or when the preoperative diagnosis was of a tumour (Fig. 7). Aspiration

FIG. 6. A-P and lateral recumbent double contrast radiograms. Above: immediately after evacuation of pus; below: four days later. Note shrinkage of cavity and absorption of most antibiotic solution (layer between air and iophendylate) that had been installed.

was chosen in the gravely ill, in acute abscesses, or in anticipation of a later resection.

These considerations were reflected in the results of surgery. Aspiration carried the highest mortality—52%. Resection either primary or secondary was associated with the death of one-third of the patients.

LATE SEQUELAE Of the 49 survivors, 45 patients were followed for more than one year, by personal examination. The late sequelae of surgery are dealt with below.

Recurrence This complication occurred four times—that is, in 8% of the survivors. All these patients had been treated by aspirations and a pneumoencephalogram had been performed at the completion of treatment and read as normal (Pennybacker, 1961). This rate of recurrence is

similar to that reported by Jooma *et al.* (1951). Two of these patients survived by later aspiration followed by resection; in both recrudescence occurred within months of the primary procedure. The two other cases were fatal and occurred several years after the first operation. The following is illustrative of such danger.

A 7 year old boy was admitted to hospital in 1952 with left-sided Jacksonian seizures. Three days later he developed a fever of 39° C, severe headache, and signs of meningitis. The CSF contained 1,000 leucocytes per cmm. A right frontal abscess was diagnosed by ventriculography. The child was treated by repeated aspirations and made a complete recovery. Eleven years later, in 1963, when on military service, he suddenly became ill. The diagnosis was meningitis; however, he lapsed into coma and died within 24 hours of the beginning of his disease. At necropsy a right frontal lobe ruptured abscess was found.

FIG. 7. Right frontal encapsulated abscess after enucleation. Above: outer surface; below: abscess cut in half.

It may be assumed that the infective organisms lay dormant in the retained capsule. This is one more case in favour of resection of the capsule whenever feasible (LeBeau, 1946; Tutton, 1953; Lewin, 1955), although some surgeons doubt the efficacy of this procedure in the prevention of recurrences (Bonnal, Descuns, and Duplay, 1960).

Neurological deficit Twenty-two out of the 45 patients followed had some degree of permanent neurological deficit (Table 13). In five of these patients the deficit could be attributed to previous tumour or trauma or surgery performed for it. Of the remaining 17 patients, four were not aware of their deficit, which consisted of hemianopia, hypoaesthesia, or minimal paresis. This

left 13 patients or 29% of the followed survivors with varying degrees of incapacitation. Three of these were totally disabled, whereas the remaining 10 were able to resume their previous duties in spite of the deficit, which was mostly hemiparesis and sometimes some dysphasia. Only one child had minimal mental retardation.

Permanent neurological deficit was commonest after resection either primary or secondary, occurring in one-third of the patients followed. Disability was least in patients treated by aspiration. Two out of 15 patients followed up had moderate hemiparesis. These disability rates are average between the data of Jooma *et al.*, (1951) and Kerr, King, and Meagher, (1958). Such results of radical *vs.* the more conservative modes of treatment put in question the justification of

TABLE 13
SEQUELAE OF BRAIN ABSCESS

Surgical procedure	Patients followed (no.)	Deficit			Seizures
		Unnoticed	Moderate	Severe	
Drainage	4	2	2		1
Aspiration	15	1	2		3
Primary resection	15		3	2 (3)*	1
Second resection	11		3	1 (2)*	1
Total followed	45†	4	10	3	6

* Figures in parentheses—patients in whom deficit was attributed to pre-existing lesion or surgery.

† Four cases of cerebellar abscess.

radical resection (LeBeau, 1946; Ballantine and Shealy, 1959).

Parietal or dominant hemisphere lesions were more prone to permanent and more severe deficit. Survivors of cerebellar surgery with any method remained symptomless.

Epilepsy Six of the patients followed up developed epileptic seizures. These constitute 15% of the survivors with supratentorial abscess. This is an unexplainably low incidence as compared with numerous other series (Jooma *et al.*, 1951; Lewin, 1955; Kerr *et al.*, 1958).

No relationship existed between the severity of neurological deficit and the occurrence of epilepsy. One patient with no permanent deficit had seizures. Another, with severe hemiparesis, also had incapacitating Jacksonian attacks.

Aspiration was apparently associated with the highest incidence of seizures.

CONCLUSIONS

There is reason to believe that the incidence of brain abscess is increasing.

Routine use of antibiotics after brain surgery or in paracranial infection does not always prevent abscess formation though it may delay its symptomatology.

The frequent use of antibiotics, even without definite diagnosis, may mask the clinical picture of brain abscess, thus making the preoperative diagnosis more difficult.

Paracranial suppuration is still the commonest source of intracranial infection.

The least disturbing and most accurate

diagnostic procedure both in terms of localization and in suggesting the nature of the lesion is angiography. Brain scan may prove to be even more accurate; moreover, it may demonstrate multiple lesions.

Preoperative use of steroids is extremely hazardous.

Sensitivity of a given organism to the antibiotic drug is a more important factor in prognosis than its particular type. Antibiotics should be administered in massive doses, when indicated and by sensitivity.

Enucleation of the abscess in the 'cold' stage after 'sterilization' by aspirations seems to be the procedure of choice. Additional damage, due to the radical surgery, should be taken into consideration.

REFERENCES

- Ballantine, H. T., Jr., and Shealy, C. N. (1959). The role of radical surgery in the treatment of abscess of the brain. *Surgery, Gynecology, and Obstetrics*, **109**, 370–374.
- Beller, A. J. (1951). The syndrome of brain abscess with congenital cardiac disease. Report on a case with complete recovery. *Journal of Neurosurgery*, **8**, 239–243.
- Bonnal, J., Descuns, P., and Duplay, J. (1960). *Les Abscès Encéphaliques à l'Ère des Antibiotiques*, pp. 154. Masson: Paris.
- Dawes, J. D. K. (1961). Discussion on intracranial complications of otogenic origin. *Proceedings of the Royal Society of Medicine*, **54**, 315–320.
- Garfield, J. (1969). Management of supratentorial intracranial abscess: a review of 200 cases. *British Medical Journal*, **2**, 7–11.
- Gregory, D. H., Messner, R., and Zinneman, H. H. (1967). Metastatic brain abscesses. A retrospective appraisal of 29 patients. *Archives of Internal Medicine*, **119**, 25–31.
- Jooma, O. V., Pennybacker, J. B., and Tutton, G. K. (1951). Brain abscess: aspiration, drainage, or excision? *Journal of Neurology, Neurosurgery, and Psychiatry*, **14**, 308–313.
- Kerr, F. W. L., King, R. B., and Meagher, J. N. (1958). Brain abscess—a study of forty-seven consecutive cases. *Journal of the American Medical Association*, **168**, 868–872.
- Kiloh, L. G., and Osselson, J. W. (1961). *Clinical Electroencephalography*, pp. 135. Butterworths: London.
- King, J. E. J., and Turney, F. (1954). Brain abscess: evolution of the methods of treatment. *Annals of Surgery*, **139**, 587–612.
- LeBeau, J. (1946). Radical surgery and penicillin in brain abscess. A method of treatment in one stage with special reference to the cure of three thoracogenic cases. *Journal of Neurosurgery*, **3**, 359–374.
- Lewin, W. (1955). Recent developments in the management of brain abscess. *British Medical Journal*, **1**, 631–634.
- Liske, E., and Weikers, N. J. (1964). Changing aspects of brain abscesses. Review of cases in Wisconsin 1940 through 1962. *Neurology (Minneapolis)*, **14**, 294–300.
- Pennybacker, J. (1961). Discussion on intracranial complications of otogenic origin. *Proceedings of the Royal Society of Medicine*, **54**, 309–315.
- Salibi, B. S. (1964). *Bacteroides* infection of the brain.

- Successful management of case with three intracranial abscesses. *Archives of Neurology*, **10**, 629–634.
- Sperl, M. P., Jr., MacCarty, C. S., and Wellman, W. E. (1959). Observations on current therapy of abscess of the brain. *Archives of Neurology and Psychiatry*, **81**, 439–441.
- Tefft, M., Matson, D. D., and Neuhauser, E. B. D. (1966). Brain abscess in children. Radiologic methods for early recognition. *American Journal of Roentgenology*, **98**, 675–688.
- Tutton, G. K. (1953). Cerebral abscess—the present position. *Annals of the Royal College of Surgeons of England*, **13**, 281–311.
- Webster, J. E., and Gurdjian, E. S. (1950). The surgical management of intracranial suppuration. Methods in diagnosis and management, and a report of 23 cases of civilian and 33 cases of military abscess. *International Abstracts of Surgery*, **90**, 209–235.
- Wechsler, I. S., and Kaplan, A. (1940). Cerebral abscess (paradoxical) accompanying congenital heart disease. Report of two cases. *Archives of Internal Medicine*, **66**, 1282–1289.