Brain abscess and subdural empyema

Factors influencing mortality and results of various surgical techniques

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SYNOPSIS The authors review the results of various surgical techniques in relation to mortality and morbidity in 100 consecutive cases of brain abscess and subdural empyema. The mortality rate is the same with total excision and fractional drainage of brain abscesses, although in acute and subacute cases slight differences between both techniques are seen. In terms of morbidity, fractional drainage appears to be more favourable than total excision. The authors believe that factors other than surgical procedure influence mortality in cases of brain abscess and subdural empyema. These factors are defined in detail.

Untreated cases of brain abscess are lethal, but, even if treated with advanced surgical techniques combined with antibiotic therapy, the mortality rate remains high.

Since Macewen's series (published in 1893) with one death in 15 operative cases of brain abscess, less favourable series were frequently reported. In the pre-antibiotic era various surgical techniques were developed in an effort to reduce the mortality rate (Dandy, 1926, 1963; Vincent *et al.*, 1937; Kahn, 1939) which nevertheless remained at 70% in this period. Since the second world war, a significant reduction of the mortality to 40% has been achieved by the introduction of specific antibiotic therapy in addition to surgery (Ballantine and White, 1953). Surgery, however, was as essential as before (Black *et al.*, 1973). Notwithstanding more advanced surgical techniques and better diagnostic and postoperative care procedures, the mortality rate has remained virtually unchanged during the last three decades, which is disappointing to many neurosurgeons. This is probably the reason why the most important techniques, such as total excision and fractional drainage, have

been in recent years alternately advocated as the method of choice for the treatment of brain abscess (Van der Werf *et al.*, 1960; Krayenbühl, 1967; Garfield, 1969; Carey *et al.*, 1972; Le Beau *et al.*, 1973; Morgan *et al.*, 1973). A comparison of the results, however, does not show essential differences.

The question arises whether there are other factors which influence mortality to a greater extent than surgical technique, and which are unrelated to the specific surgical technique, in which case the method of choice should be the simplest and less traumatic one. The aim of this paper is to attempt to help answer this question. Since clinical course, diagnosis, and treatment of subdural empyema pose related problems, this entity has been included.

METHODS

CLINICAL MATERIAL In the present study, a series of 100 consecutive cases of proved brain abscess and subdural empyema is reviewed. All patients were admitted to the neurosurgical department of the Wilhelmina Gasthuis, University Hospital, from 1956 through 1973 and treated by the neurosurgical staff and residents. All data were obtained from the case histories. No special long-term follow-up was done, but all surviving patients were seen at our outpatient clinic at regular intervals during one to five years after surgery. A number of factors were considered which

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could be important in relation to mortality and morbidity of brain abscess and subdural empyema. This series includes 83 cases of intracerebral abscess (one patient had two brain abscesses within an interval of four weeks) and 18 cases of subdural empyema. Eighty-nine patients underwent surgery: 73 for intracerebral abscess and 16 for subdural empyema.

In reviewing the case reports, there appeared to be no special system for the choice of operative procedure. In cases of subdural empyema, drainage of the subdural space was performed, either *via* multiple burr holes or a large bone flap, both combined with specific antibiotic therapy. Various surgical techniques were used in cases of brain abscess: fractional drainage of the abscess cavity, total excision, in some cases burr hole drainage followed later by total excision, and in two cases single aspiration. The choice of operation was largely determined by the surgeon's personal preference and entirely unrelated to the patient's age, general condition, or neurological state. Sometimes an unspecified space occupying lesion rather than an abscess was diagnosed and therefore excision of the abscess was performed during the intracerebral exploration, which was not a premeditated plan. As the choice of surgical treatment during the reviewed period was fairly arbitrary, it was possible to compare the results of the different methods rather objectively.

SURGICAL TECHNIQUES Discouraged by the disastrous results of the old efforts of wide open drainage, Dandy introduced the technique of tapping the abscess with a ventricular needle through a burr hole 'as nearly over the most superficial part of the abscess as can be estimated' (Dandy, 1926, 1963). This tapping could be repeated, if necessary, at increasingly long intervals of time. Dandy advised against aspiration or irrigation, because 'both do add very definite traumatic insults' (Dandy, 1963). Nevertheless, the technique of 'repeated aspiration' has been mentioned as a method of treatment in more recent literature (Ballantine and White, 1953; Krayenbühl, 1967; Le Beau *et al.*, 1973). In our opinion, both tapping and aspiration have the following disadvantages and hazards:

1. Aspiration of a larger amount of pus, especially in acute cases with a thin abscess wall, can easily lead to collapse of the abscess cavity and multiloculation. It will then be difficult, at subsequent punctures, to drain all parts of the multiloculated abscess; hence Dandy's advice to postpone tapping until a firm capsule has been formed. This course of action, however, carries in itself a great risk and has largely been abandoned (Botterell and Drake, 1952).

2. A repeated aspiration is deemed necessary when the patient's neurological state deteriorates, which is to say that his intracranial pressure rises, whereby his brain stem function is endangered intermittently.

3. Repeated punctures damage the overlying cortex and give greater risk of contamination of the subarachnoid and subdural space and cerebral tissue *via* various puncture tracts.

For these reasons, we prefer the technique of 'fractional drainage', as described elsewhere (Van der Werf *et al.*, 1960). *Via* an indwelling small rubber catheter, introduced through a burr hole, a small amount of pus is evacuated, just enough to relieve the pressure inside the abscess cavity, and specific antibiotics are instilled daily. By instilling some micronized barium sulphate (Steripaque) in the abscess cavity, the gradual shrinking of the abscess can be visualized by radiography (Figure). In our opinion, it is essential to continue this procedure for some weeks until no, or only very little, pus can be removed, until the bacteriological specimens are repeatedly negative, and until the abscess cavity has shrunk. During this treatment the patient is also kept on systemic antibiotics.

The technique of 'fractional drainage' has the advantage of being a simple procedure, without great risk of considerable damage to the oedematous brain. It also eliminates the above-mentioned disadvantages of Dandy's technique.

ANALYSIS OF CASES Table 1 shows the incidence of brain abscess and subdural empyema in the various age groups and in males and females respectively. From this table it appears that brain abscess occurs twice as frequently in males as in females, and is more frequent in younger patients.

TABLE 1

RELATIONSHIP BETWEEN AGE AND SEX AND BETWEEN AGE AND PREOPERATIVE COURSE IN PATIENTS WITH INTRACRANIAL ABSCESS

Age (yr)	Male	Female	Total no.	Acute	Subacute
0-10	11 (3)	7 (4)	18 (7)	4 (3)	14 (4)
11-20	11 (1)	11 (3)	22 (4)	4 (1)	18 (3)
21-30	11 (2)	5 (3)	16 (5)	3 (1)	13 (4)
31-40	9 (4)	4 (1)	13 (5)	5 (3)	8 (2)
41-50	10 (5)	3 (1)	13 (6)	5 (2)	8 (4)
51-60	9 (4)	2 (1)	11 (5)	3 (2)	8 (3)
61-70	4 (4)	1 (0)	5 (4)	2 (2)	3 (2)
71-80	2 (2)	-	2 (2)	1 (1)	1 (1)
Total	67 (25)	33 (13)	100 (38)	27 (15)	73 (23)

The number of deaths in each group is noted in parentheses.

FIGURE Fractional drainage of a temporal lobe abscess, respectively one day, two weeks, and five weeks after operation.

In the lower age groups the female mortality rate seems to be somewhat higher than the male rate, but this is probably not statistically significant. Comparing the mortality rate below and above 40 years of age, one sees an important difference: 30% versus 55%. The overall mortality is 38%.

Table 1 also provides data about the pre-operative course in the various age groups. What is meant by acute course is that the symptomatology which leads to surgery, or to death if the patient is not operated upon, develops within seven days. In subacute cases the onset of the patient's complaints is more protracted. It appears that the course is acute in 27% of the cases, with an equal distribution over the various age groups. The mortality rate in acute cases of brain abscess and subdural empyema is much higher than in subacute cases: 56% and 32% respectively.

The primary origin of brain abscess and subdural empyema is listed in Table 2. In this series 52% of the cases of intracranial abscess were caused by otogenic or paranasal infections. The third most important cause is a cardiac disease, mostly of the congenital type with an open septum (11%). All other causes accounted for 5% or fewer cases.

With few exceptions, there seems to be no relationship between mortality and the aetiology of brain abscess. The metastatic brain abscess of pulmonary origin seems to have an unfavourable prognosis. Five patients with brain abscess, two following bronchopneumonia and three caused by bronchiectasis, died within a few days or weeks after admission.

TABLE 2

RELATIONSHIP BETWEEN MORTALITY AND AETIOLOGY IN 100 CASES OF BRAIN ABSCESS AND SUBDURAL EMPYEMA

Origin	Cases (no.)	Deaths (no.)
Otogenic	28	9
Paranasal sinusitis	24	6
Metastatic (heart)	11	4
Metastatic (lung)	5	5
Metastatic (miscellaneous)	2	1
Post-craniotomy	3	2
Post-traumatic	5	0
Post-dental infection	1	0
Meningitis	4	2
Unknown	17	9
Total number	100	38

One patient, a 14 year old boy who was suffering from bronchiectasis, was comatose and moribund upon admission. He died before surgery could be undertaken. At necropsy a left temporal and a right occipital lobe abscess were found.

Another patient, a 6 year old boy, had been admitted to another hospital because of lymphoblastic leukaemia complicated by bronchopneumonia and purulent meningitis. He was transferred to our hospital because of an incomplete transverse myelitis. He also had epileptic seizures. His cerebral disease was, however, not diagnosed until after death. At necropsy he appeared to have a right frontal lobe abscess with intraventricular rupture.

A 28 year old female, suffering from a bronchiectasis and pneumonia, was admitted because of meningitis and an acute grade 4 brain abscess which was treated by fractional drainage. She died some hours after surgery of bronchospasm and pulmonary oedema.

A 22 year old female, who was suffering from bronchiectasis, was admitted to our hospital because of signs of meningitis and of a space occupying lesion of the left hemisphere. A deeply placed left temporal lobe abscess was diagnosed and drained immediately. Some days after surgery she showed severe signs of increased intracranial pressure and died. At necropsy six differently located brain abscesses were found.

A 72 year old male developed meningitis some weeks after bronchopneumonia. He received antibiotics and several lumbar punctures were done. After 10 days, he showed signs of a space occupying lesion of the left hemisphere and became semi-comatose. A deeply placed left temporal lobe abscess was diagnosed by angiography. The patient was transferred to our clinic and the abscess was treated with fractional drainage and in the usual fashion with antibiotics. In the following weeks he developed pneumonia, pleuritis, and uraemia. He died four weeks after surgery. At necropsy, a large temporal lobe abscess ruptured into the ventricle, basal meningitis, and pulmonary oedema were found.

A more favourable group seems to be the brain abscesses due to trauma of the skull, mostly compound skull fractures. There were five such cases in our series. All these patients were young, between 6 and 35 years of age, healthy, and in a good overall condition before the accident. All were alive several years after surgery.

The organisms responsible for brain abscess and subdural empyema are summarized in Table 3. As in some of the other tables, the total number of cases is 101, because one patient had

TABLE 3

RELATIONSHIP BETWEEN MORTALITY AND RESPONSIBLE ORGANISM IN 100 CASES OF BRAIN ABSCESS AND SUBDURAL EMPYEMA

Organism	Cases (no.)	Deaths (no.)
<i>Streptococcus</i>	30	10
<i>Staphylococcus</i>	9	2
<i>B. proteus</i>	5	2
<i>Pneumococcus</i>	5	1
<i>Clostridium</i>	3	0
<i>Klebsiella</i>	1	1
<i>Haemophilus</i>	1	1
<i>Escherichia coli</i>	1	0
<i>B. tubercul.</i>	2	2
<i>Actinomyces</i>	1	1
Mixed culture	10	5
Mixed culture of anaerobic organisms	8	2
Unknown (no culture grown in operated cases)	15	1
Unknown (no surgery, no postmortem examination)	10	10
Total number	101	38

two brain abscesses with a four weeks' interval in between, with a different localization, a different organism, and a different surgical treatment. Both abscesses are therefore tabulated separately. The mortality rate of the streptococcal abscesses, compared with that of staphylococcal abscesses, seems to be fairly high. But in the group of streptococcal abscesses the abscess was missed at operation in three cases, which unfavourably influences the mortality rate of this group. The difference between the two groups might, therefore, not be significant. Two cases of tuberculous brain abscesses were both lethal.

The first patient, an 11 year old girl, was found to have a subacute abscess of unknown origin. At the time of operation she was comatose and in very poor condition. A large unencapsulated temporal lobe abscess was found and excised. This subsequently appeared to be of tuberculous nature. She died four days after surgery.

The second patient, a male, had been treated five years earlier for cavernous pulmonary tuberculosis and had had a more recent operation for intestinal tuberculosis. His subacute neurological deterioration was not diagnosed until after death. At necropsy a left cerebellar tuberculous abscess was found.

In these cases, the grade 4 neurological condition and the diagnostic failure were probably respectively responsible for the lethal course, rather than the tuberculous origin.

In 10 cases, a mixed culture of two or three strains, principally *Staphylococcus*, *Streptococcus* and *Proteus*, was obtained from either the same abscess or from multiple abscesses containing different organisms. The mortality rate of two cases of multiple abscesses in this group was 100%. The presence of more than one strain in the same abscess does not seem to have any specific influence upon mortality. Only one patient died out of 15 in whom the bacteriological examination was negative after surgery. This mortality rate is remarkably low and seems to be significant.

Ten other patients in whom the organism responsible for brain abscess was unknown died because they had no surgery. No postmortem bacteriological examination was done in these cases.

The possible influence of the localization on mortality in acute and subacute cases of brain abscess and subdural empyema can be read from Table 4. Except for the occipital localization, acute brain abscesses show a higher mortality than subacute ones regardless of localization. With a few exceptions, there appear to be no significant differences in mortality among the various localizations. The mortality rate in occipital lobe abscess is high (50%) compared

with that in other localizations, owing to the fact that these abscesses were missed more frequently at operation and were consequently not properly treated (three cases). It is likely that this has to do with the greater difficulty in interpreting carotid angiograms in cases of occipital space occupying lesions. It also appears that cases with multiple localization have a worse prognosis as regards survival (two deaths out of three), although the series is too small to draw conclusions.

An analysis of the pathogenesis of brain abscess and subdural empyema in the various sites shows that 12 out of 16 cases of supratentorial subdural empyema were caused by a preceding sinusitis, as were nine out of 22 frontal lobe abscesses. The infratentorial subdural empyema and most of the temporal lobe abscesses were of otogenic origin.

The relationship between mortality and pre-operative neurological state in cases of brain abscess and subdural empyema is tabulated in Table 5. In the not operated group the state at admission is noted. The neurological state is graded from I to IV, according to the level of consciousness, as described by Carey *et al.* (1972) and Morgan *et al.* (1973). The surgical mortality rate rose significantly in relation to worsening neurological state and was 15.8% in grade I patients, 26.2% in grade II, 33.3% in grade III, and 58.2% in grade IV.

TABLE 4

RELATIONSHIP BETWEEN MORTALITY AND LOCALIZATION IN ACUTE AND SUBACUTE CASES OF BRAIN ABSCESS AND SUBDURAL EMPYEMA

Localization	Acute (≤ 7 days)	Subacute (> 7 days)
Intracerebral		
Frontal	6 (4)	16 (1)
Temporal	6 (5)	23 (8)
Parietal	1 (1)	9 (3)
Occipital	3 (1)	7 (4)
Cerebellar		9 (3)
Multiple		3 (2)
Subdural empyema		
Supratentorial	10 (4)	6 (1)
Intratentorial	1 (0)	1 (1)
Total number	27 (15)	74 (23)

The number of deaths in each group is in parentheses.

TABLE 5

RELATIONSHIP BETWEEN MORTALITY AND PRE-OPERATIVE NEUROLOGICAL STATE (NUMBER OF DEATHS)

Neurological state	Operated	Not operated
Grade I		
Alert, slight neurological symptoms	19 (3)	1 (1)
Grade II		
Drowsy and/or moderate to severe neurol. sympt.	42 (11)	7 (7)
Grade III		
Subcomatose, responsive to painful stimuli	15 (5)	2 (2)
Grade IV		
Not responsive to painful stimuli or with disturbance of vital functions	12 (7)	2 (2)
Total number	88 (26)	12 (12)

An analysis was made of the presumed cause of death in 12 non-surgical and 26 surgical cases of brain abscess and subdural empyema (Table 6). Six out of 12 cases were admitted to the University Hospital in too poor a neurological state, or were deteriorating too rapidly (four grade IV patients, one grade III, one grade II) to be operated upon. Among this group, two patients appeared to have multiple abscesses. In the other four cases the severe neurological state could be attributed to a recent lumbar puncture performed elsewhere, which was followed by acute deterioration.

TABLE 6
PRESUMABLE CAUSE OF DEATH IN 38 CASES OF BRAIN ABSCESS AND SUBDURAL EMPYEMA

Cause of death	Operative procedure			Total
	Drainage	Excision	Subd. emp.	
Ventriculitis-meningitis	3	4		7
Nature of lesion	6	3	3	12
Postoperative bleeding		1		1
Medical complications			1	1
Abscess missed at surgery				5
Diagnostic failures				6
Moribund on admission				6
Total	9	8	4	38

Six other patients died because of diagnostic failures. Two of them were diagnosed as basal meningitis and as a consequence had several spinal taps. Another, suffering from a colon carcinoma, was diagnosed as suffering from a cerebral metastasis. He died during his course of radiotherapy. One patient was thought to have severe brain oedema some days after surgery for brain tumour. At necropsy, an abscess was found in the operative field. In two cases the abscess symptomatology was masked by severe diseases elsewhere in the body (lymphoblastic leukaemia and bronchopneumonia in one case, and cavernous pulmonary and intestinal tuberculosis in another).

Out of 26 surgical deaths, five patients died because of technical failures. At surgery (mostly open explorations) the accompanying cerebral oedema was obvious but no abscess was found. In all these cases, a bone flap was removed as an external decompression procedure. As mentioned

above, in three cases the abscess was found at necropsy to be located in the occipital lobe, probably because of the poor visualization of space occupying lesions in this area as obtained by carotid angiograms. In another case, a subdural empyema was diagnosed and subsequently drained, but the patient deteriorated progressively. At postmortem examination a temporal abscess was also found.

Eight patients, five in grade IV and three in grade III, whose condition was already irretrievable before surgery, died after operation. Progressive and untreatable cerebral oedema was responsible for the lethal outcome in two cases of subdural empyema. Another patient died some hours after surgery from bronchospasm and acute pulmonary oedema. One case of congenital heart disease died from cardiac failure. In seven cases a complicating meningitis or ventriculitis resulted in death. The abscess may have ruptured spontaneously into the ventricular system in some, but in most cases the ventriculitis undoubtedly was caused by opening a ventricle while excising a paraventricular abscess or passing beyond the abscess cavity into the ventricle during a drainage procedure. Post-operative bleeding after excision of a cerebellar abscess caused one death and another patient died of pneumonia 12 days after drainage of a subdural empyema.

In Table 7 we compare the various surgical techniques in relation to mortality in acute and subacute cases. As discussed above, the total number of cases in this table is 101. Ten patients

TABLE 7
RELATIONSHIP BETWEEN MORTALITY AND SURGICAL TREATMENT IN ACUTE AND SUBACUTE CASES OF BRAIN ABSCESS AND SUBDURAL EMPYEMA

Treatment	Acute	Subacute	Total
Single aspiration		2 (0)	2 (0)
Fractional tube drainage	7 (5)	27 (4)	34 (9)
Total excision	4 (1)	14 (4)	18 (5)
Excision cerebellar abscess		4 (1)	4 (1)
Tube drainage, followed later by total excision		10 (2)	10 (2)
Drainage subdural empyema	10 (3)	6 (1)	16 (4)
Abscess missed at surgery	2 (2)	3 (3)	5 (5)
Not operated	4 (4)	8 (8)	12 (12)
Total number	27 (15)	74 (23)	101 (38)

The number of deaths is given in parentheses.

were treated by excision of the abscess cavity after a period of fractional drainage or some time after completion of the same. In the latter, the shrunk abscess wall was excised in view of the presumed epileptogenic hazard of a retained abscess capsule. In the last six years this policy was abandoned without harmful consequences. In some cases, secondary excision was performed when fractional drainage—usually as a result of capsule collapse and subsequent multiloculation—proved to be insufficient to improve the patient's neurological state.

On the whole, there appears to be no significant difference in mortality between the various surgical techniques. Looking at the acute and subacute cases separately the mortality rate seems to be slightly higher for fractional drainage in acute cases, although the total number of cases is too small for precise comparison. In subacute cases, the fractional drainage was somewhat more favourable than total excision with regard to mortality.

The surgical mortality of the combined primary and secondary excision, the combined aspiration and drainage, and the drainage of subdural empyema was 25% for all subgroups (Table 8). This table also reveals that the remaining neurological deficit in the survivors, after a follow-up period ranging from one to five years, was higher in the excision group, with a tendency towards the more severe form. This may reflect the greater damage to the oedematous and friable brain when performing excision rather than the less traumatizing drainage procedure.

It was also learned, from the case histories, that the incidence of postoperative seizures was quite low. However, most patients were lost to follow-up after an average period of five years. Only two

patients manifested seizures of the grand mal type, one after excision and one after drainage. One patient was referred to us 10 years after aspiration of an abscess because of an isolated seizure which was easily controlled with anti-convulsants. Two additional patients showed an epileptic focus on their EEG without manifest seizures.

Table 9 shows the overall mortality, the mortality in patients older than 40 years, and the surgical mortality during three consecutive six year periods. From this table, the disappointing conclusion has to be drawn that the mortality rate in the various groups has scarcely decreased in more recent years and that the improvement in diagnostic and surgical techniques has not found expression in the results of the treatment of brain abscess and subdural empyema.

TABLE 9

MORTALITY RATE IN 100 CASES OF BRAIN ABSCESS AND SUBDURAL EMPYEMA IN THREE DIFFERENT PERIODS BETWEEN 1956 AND 1973

Period	Overall mortality	Mortality in patients > 40 years of age	Operative mortality
1956-61	14/42—33.3%	3/10—30%	5/33—15%
1962-67	13/32—40.6%	6/8—75%	11/30—37%
1968-73	11/26—42.3%	8/13—61.5%	5/21—24%

DISCUSSION

The mortality rate of brain abscess and subdural empyema in this series is 38% with a surgical mortality rate of 25%. These figures are approximately similar to those reported in other series (referred to above) including Kiser and Kendig (1963). In Table 10, the most important series in

TABLE 8

POSTOPERATIVE STATE IN 84 CASES OF BRAIN ABSCESS AND SUBDURAL EMPYEMA

Surgical procedure	Neurological deficit			Deaths (no.) (%)	
	None	Slight	Severe		
Total excision (primary and secondary)	11	10	3	8	25
Fractional drainage	17	9	1	9	25
Drainage subdural empyema	5	3	4	4	25

TABLE 10

MORTALITY IN VARIOUS SERIES OF BRAIN ABSCESS AND SUBDURAL EMPYEMA

Authors	Overall mortality (%)	Surgical mortality (%)
Ballantine and White (1953)	34.5	34.5
Kiser and Kendig (1963)	50.0	30.0
Newlands (1965)	27.5	
Krayenbühl (1967)	30.0	26.0
Garfield (1969)	40.0	32.0
Carey <i>et al.</i> (1972)	53.0	21.5
Le Beau <i>et al.</i> (1973)		31.0
Morgan <i>et al.</i> (1973)	36.4	29.1
Present series	38.0	25.0

the period between 1953 and 1973 are listed. This table shows that the overall results, as far as mortality is concerned, showed absolutely no change during the last 20 years. In the individual publications, only Krayenbühl (1967) reported an improvement of his results in the last six year period compared with the previous 15 years. Other authors (Garfield, 1969; Le Beau *et al.*, 1973), however, could not demonstrate such a progressive improvement in their subsequent periods. Nor do our results show an improvement in the last six year period (Table 9). In cases of brain abscess the seemingly better results are attributed to the application of total excision by some authors (Krayenbühl, 1967; Le Beau *et al.*, 1973). In Krayenbühl's series the mortality rate in 14 cases of repeated aspiration was 21.4%, and in 90 cases of radical excision between 1945 and 1965 it was 22.2%.

Le Beau *et al.* (1973) compared the results in 240 cases treated by total excision (mortality 27%) and in 32 cases treated by aspiration (mortality 65%). Their aspiration techniques are not further defined. Judging by these results, both authors prefer the total excision to the various aspiration techniques. Carey *et al.* (1972) found that abscess drainage was associated with approximately the same mortality as excision (19% vs 22%). They give some preference to 'abscess drainage, as a form of therapy, since it was employed with no increased mortality in neurological decompensated patients'.

In our series the mortality rate in fractional drainage as well as total excision was 25%. The same mortality was seen in cases of subdural empyema. From these data, we can conclude that the form of surgery is of only minor importance as far as mortality is concerned. In terms of morbidity, however, fractional drainage appears to be more favourable than total excision (Table 8). Therefore, we prefer the use of fractional drainage, especially in subacute cases of brain abscess. In acute cases this procedure may not always be sufficient to relieve the high intracranial pressure, because of the disproportional oedema (Botterell and Drake, 1952; Le Beau *et al.*, 1973). In these cases total excision may be life saving at the cost of a greater morbidity. In contrast with some reports in the literature (Carey *et al.*, 1972; Le Beau *et al.*, 1973), the incidence of post-operative epilepsy is very low (3%) and seems to

be a negligible factor in the choice of surgical treatment.

Mortality in brain abscess and subdural empyema appears to be influenced by a number of factors unrelated to the type of surgery:

AGE The chance of dying increases with rising age (Table 1), which probably reflects the lower resistance of the aging body to any noxious influence.

PREOPERATIVE COURSE In our series, the acute cases of brain abscess and subdural empyema had a more unfavourable prognosis with a mortality rate of 56%, *versus* 32% in subacute cases. This is in accordance with the findings of Le Beau *et al.* (1973). The acute course sometimes results in a too late diagnosis or in a too late transferral of the patient for surgery. On the other hand, the surgical results in acute cases are less favourable than in the subacute ones.

AETIOLOGY From various reports in the literature (Carey *et al.*, 1972; Le Beau *et al.*, 1973), it can be deduced that the mortality rate in metastatic brain abscesses is relatively high. In our series, the metastatic abscesses from the lung were 100% lethal. This is even more striking when compared with post-traumatic abscesses (Table 2). These last patients were all young and healthy before the accident. Therefore, it is likely that in cases of metastatic abscess the patients' resistance is greatly decreased by the general infectious condition.

PREOPERATIVE NEUROLOGICAL STATE Several authors have mentioned the close correlation between survival and preoperative level of consciousness in patients with brain abscess or subdural empyema (Newlands, 1965; Garfield, 1969; Carey *et al.*, 1972; Morgan *et al.*, 1973). Our findings agree with this; the mortality rate ranging from 15.8% in grade I patients to 58.2% in grade IV (Table 5). Further analysis shows, however, that a relatively large number of deceased grade IV patients had shown an acute course before surgery. Therefore, the preoperative course and neurological state are not entirely unrelated with respect to mortality in grade IV patients. This correlation between preoperative course and neurological state was not seen in grade I to III patients.

LOCALIZATION OF BRAIN ABSCESS This also appeared to be a factor in relation to mortality in some cases. The unfavourable prognosis of multiple abscesses has been pointed out by some authors (Carey *et al.*, 1972; Le Beau *et al.*, 1973). The incidence of multiple abscesses was low in our series, but the mortality rate also seems to be high: two deaths out of three. Also, in single abscesses the localization may give rise to difficulties, as shown by an analysis of cases in which the abscess was missed at surgery. In all these cases the presence of an abscess was suspected before surgery. The carotid angiograms showed signs of a space occupying lesion somewhere in the posterior half of the cerebral hemisphere without precise localization. At postmortem examination, three abscesses appeared to be localized in the extreme posterior part of the occipital lobe, two were situated deeply temporobasal. A brainscan would have been very helpful in these cases. If treated adequately, either by total excision or by fractional drainage, no correlation was found between mortality and localization.

DIAGNOSTIC FAILURES The danger of lumbar puncture in abscess or subdural empyema has been frequently recognized (Dandy, 1963; Garfield, 1969; Carey *et al.*, 1972; Morgan *et al.*, 1973). Spinal taps are not infrequently done in those patients, who are suspected of having meningitis, which is, in fact, a sequela of unsuspected brain abscess or subdural empyema. When contaminated spinal fluid is found the diagnosis of meningitis seems to be confirmed and spinal taps are repeated for intrathecal administration of antibiotics, resulting in acute deterioration or demise. Therefore, in a patient suspected of having meningitis, but also showing lateralizing symptoms, echoencephalography should be performed first. When a midline shift is found the next step should be brainscanning or carotid angiography rather than lumbar puncture. Once in a while, a severe infectious disease elsewhere in the body can cause a metastatic brain abscess, but, as is seen in two of our cases in which the diagnosis was missed, it may also divert the attention from the neurological symptoms caused by a brain abscess.

POSTOPERATIVE COMPLICATIONS Any type of surgery can be followed by lethal unspecific

complications such as pulmonary or thromboembolic processes, or postoperative haematomas. More directly related to brain abscess or subdural empyema are cerebral oedema and contamination of spinal fluid compartments. In our series we had a complicating ventriculitis or basal meningitis which led to death in some cases of excision as well as in drainage procedures. A proper technique and great care should be employed in puncturing an abscess cavity to avoid this complication, as already pointed out by Dandy (1963).

In conclusion, it can be stated from this study that the overall mortality in brain abscess and subdural empyema is determined considerably by missing an abscess at surgery or by ruling out surgery for whatever reason. Most other factors contributing to mortality, as far as brain abscess is concerned, exist before surgery and are unrelated to the type of surgery, be it total excision or fractional drainage. Considering the results in our drainage group both in regard to mortality and morbidity, we disagree with some other authors (Krayenbühl, 1967; Le Beau *et al.*, 1973), who have maintained that radical removal of a brain abscess is necessary.

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