Experience with brain abscesses

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Eighty-six patients with brain abscesses were seen at the University of
Minnesota Hospitals from 1946–1965, and 46 died, a 53% mortality. Multi-
ple and brain stem abscesses accounted for several fatalities, while delayed
and missed diagnosis accounted for one third of the deaths. Evidence of in-
fection was often minimal in patients with brain abscess. Lumbar puncture
as a diagnostic tool was inaccurate and occasionally fatal. Brain scan, elec-
troencephalography, and angiography were the best diagnostic tests. Drainage
and excision were each associated with approximately a 20% mortality. The
most pertinent correlation regarding treatment, however, was that of in-
creasing mortality with deteriorating preoperative neurological status. Post-
operative deaths were due to failure in locating the abscess at surgery or un-
toward events such as cerebritis, edema, or excessive bleeding at the operative
site.

KEY WORD brain abscess

Ev er since the turn of the century neu-
rosurgeons have been trying to equal
the results of Macewen18 in the treat-
ment of brain abscess. In his series only one
of 15 patients died. Despite great advances
in diagnostic and neurosurgical techniques
and a variety of antibiotics, the mortality as-
associated with brain abscess remains distress-
ingly high. Jooma, et al.,13 reported a 40%
mortality in the treatment of 295 brain ab-
cesses. Kiser and Kendig15 noted 32 deaths
among 101 patients with intracerebral ab-
cesses. Garfield8 observed a 40% mortality
for 200 treated, supratentorial abscesses.

Eighty-six cases of brain abscess were seen
at the University of Minnesota Hospitals from
1946 to 1965, and 46 patients died, a 53%
mortality. The following report comprises an
analysis of these deaths and includes detailed
observations on diagnostic tests for brain ab-
cess and the results of surgical therapy.

Bacteriologic analysis indicated that ab-

scesses containing multiple and anaerobic
organisms increased in the later years of this
study. Fourteen of the 18 patients with brain
abscesses containing only anaerobes sur-
vived with surgery, however. As noted by
Heineman and Braude,11 anaerobic brain ab-

cesses per se do not prejudice against sur-

vival. Because no correlation could be found
between abscess flora and survival, this pa-

rameter is not considered further in this re-

port.

Clinical Material

The 86 cases included in this chart study
consist of individuals hospitalized at the Uni-
versity of Minnesota Hospitals from 1946
through 1965. Brain abscess or localized
cerebritis was histologically proven in each
instance by surgery or autopsy. There were
78 abscesses of the cerebral hemispheres and
eight of the posterior fossa (six cerebellar,
two pontine). Patients with miliary abscesses
TABLE 1
Mortality associated with different types of brain abscess

<table>
<thead>
<tr>
<th>Source or Type of Abscess</th>
<th>Total Cases</th>
<th>Died</th>
</tr>
</thead>
<tbody>
<tr>
<td>metastatic (normal patients)</td>
<td>33</td>
<td>18</td>
</tr>
<tr>
<td>metastatic (R-L shunt)</td>
<td>20</td>
<td>15</td>
</tr>
<tr>
<td>sinus or mastoid infection</td>
<td>25</td>
<td>9</td>
</tr>
<tr>
<td>trauma or osteomyelitis of skull</td>
<td>8</td>
<td>4</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>86</strong></td>
<td><strong>46</strong></td>
</tr>
</tbody>
</table>

from terminal sepsis were excluded as were a few patients who developed an abscess after a neurosurgical procedure.

Four etiological groups of brain abscesses were distinguished in the clinical material:

1. Hematogenous or metastatic abscesses in normal individuals (33 cases).
2. Hematogenous or metastatic abscesses in cyanotic patients having right-to-left shunts because of congenital heart disease or pulmonary A-V malformations (20 cases).
3. Abscesses secondary to sinus or mastoid infection (25 cases).
4. Abscesses consequent to trauma or osteomyelitis of the skull (8 cases).

These few cases precluded significant analysis of this subgroup.

Analysis of Cases

Mortality and Cause of Death

Table 1 shows the overall mortality associated with the different abscess types. Table 2 indicates the reasons for the patient's death. Although most patients clearly had a predominant reason for death, several factors could be implicated in others. In these few cases the most prominent reason for death has been assigned. Two individuals who had difficulty with diagnostic procedures (lumbar puncture and ventriculogram) and died following surgery are listed as surgical deaths. Seven patients had multiple lesions and two had pontine abscesses. Although multiple lesions occurred in all etiological categories, they were of hematogenous origin in four instances.

Difficulty in establishing diagnosis proved to be the most significant cause of death. Table 3 analyzes the diagnostic difficulties. A hematogenous abscess in an otherwise normal individual was the hardest to diagnose. This failure led directly to death in seven patients. Brain abscesses commonly have been associated with cyanotic congenital heart disease, sinus mastoid infections, trauma, and osteomyelitis of the skull. In these etiological groups, diagnostic failure was rarely a cause of death.

Temperature and Peripheral Blood Findings

Brain abscess diagnosis may be enhanced if evidence of infection is ascertained as manifested by fever, increased erythrocyte sedimentation rate, leukocytosis, and increased numbers of polymorphonuclear cells in the peripheral blood. Table 4 examines these parameters.

Temperature. Temperature was estimated by perusal of the temperature graph for the first 4 days of the patient's hospitalization when differential diagnoses would have been considered. Forty patients (47%) had elevated temperatures, the average being 100°F. Thirteen had subnormal temperatures. Contrary to some earlier opinions, no convincing evidence was found that brain abscess is usually associated with subnormal temperatures. Six patients had fever greater than 101.5°F, but five had concomitant meningitis, local, or systemic infections.

White Blood Cell Count. The white blood cell count (WBC) was below 10,000/mm³ in 40% of patients. Ten percent of the patients had more than 20,000 WBC/mm³ in
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Table 3: Diagnostic difficulties

<table>
<thead>
<tr>
<th>Difficulty</th>
<th>Abscess Type*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>MET</td>
</tr>
<tr>
<td>diagnosis not made</td>
<td>7</td>
</tr>
<tr>
<td>death following lumbar puncture</td>
<td>0</td>
</tr>
<tr>
<td>cardiac arrest following angiography</td>
<td>0</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>7</strong></td>
</tr>
</tbody>
</table>

* MET = Metastatic abscess in otherwise normal individuals.
CHD = Metastatic abscess in individuals having right to left shunts.
S/M = Abscess secondary to sinus or mastoid infection.
TR/OST = Abscess secondary to trauma or osteomyelitis of the skull.

Table 5 summarizes the relative success and hazards of these tests.

**Brain Scan.** Abscess localization was accurate in each of four instances where this technique was employed. No false negative results and no morbidity were noted.

**Angiography.** Carotid angiography was used as the sole contrast study in 26 patients and localized the abscess 22 times, a 85% accuracy. The so-called "ring sign," often diagnostic of an abscess, was observed seven times in chronic well-encapsulated abscesses. Thirty-four patients received carotid arteriograms, with one death secondary to cardiac arrest in a 2 1/2-year-old girl who had an abscess associated with cyanotic, congenital heart disease.

**Ventriculography.** Ventriculography was used as the only diagnostic test 11 times and localized the lesion in eight instances (73% accuracy). Another eight patients had angiography in conjunction with ventriculography. One patient lapsed into coma following

The peripheral blood secondary to meningitis or systemic infections.

**Polymorphonuclear (PMN) Reaction.** While three quarters of the patients evidenced neutrophilia (77% average), one quarter had less than 70% PMN's in their peripheral blood.

**Erythrocyte Sedimentation Rate (ESR).** The ESR in patients with metastatic, sinus mastoid, or traumatic abscesses ranged from 5 to 110 mm/hr, with a median value of 45 to 50 mm/hr. It was normal only in two patients, both with chronic abscesses. In cyanotic, polycythemic patients having abscesses secondary to congenital heart disease, the ESR ranged from 0 to 3 mm/hr. The ESR could not be used as a diagnostic aid in these individuals who normally have low ESR's secondary to their polycythemia.

**Diagnostic Procedures**

Brain abscess diagnosis is often made possible by specialized diagnostic procedures.
TABLE 6
Summary of cerebrospinal fluid findings

<table>
<thead>
<tr>
<th>Findings</th>
<th>Pressure</th>
<th>Protein</th>
<th>Glucose</th>
<th>Cells</th>
<th>Gram Stain</th>
<th>Culture</th>
</tr>
</thead>
<tbody>
<tr>
<td>abnormal (%)</td>
<td>67</td>
<td>67</td>
<td>25</td>
<td>67</td>
<td>25</td>
<td>13</td>
</tr>
<tr>
<td>normal (%)</td>
<td>33</td>
<td>33</td>
<td>75</td>
<td>33</td>
<td>75</td>
<td>87</td>
</tr>
</tbody>
</table>

ventriculography and died after surgery. Although the patient's death has been listed as surgical, the ventriculographic procedure contributed significantly to his death.

Pneumoencephalography. Pneumoencephalography was used as the sole diagnostic procedure in three instances and correctly localized the abscess twice.

Electroencephalography. Electroencephalograms were done in approximately half of all patients with hematogenous abscesses but rarely were done in patients with abscesses secondary to sinus mastoid infection or trauma. Ipsilateral abnormalities, usually high amplitude delta waves, were noted in 25 of 30 EEG's, and the delta focus corresponded to the abscess site in 14 cases.

Lumbar Puncture. This test was performed on 62 individuals. Analysis of the cerebrospinal fluid with particular reference to glucose, cells, gram stain, and culture traditionally has been done as an aid to abscess diagnosis. Table 6 summarizes these laboratory findings. Only nine of 39 patients had glucose values below 40 mg%, and all of these had a concomitant meningitis. The CSF glucose was normal in three quarters of the cases with established brain abscesses. Twenty-two of 61 patients had less than 10 WBC/mm³, and 19 of these had 5 WBC/mm³ or less. Thus, approximately one third of the patients with well-established brain abscesses showed no significant CSF pleocytosis. The CSF gram stains were positive in seven of 28 instances. Meningitis was also present in all seven of these patients. In two of the seven cases, subsequent abscess cultures were performed but neither culture showed an exact correlation with bacteria suspected from gram stain morphology. Cerebrospinal fluid cultures were sterile in 32 of 37 instances. While bacterial growth occurred in spinal fluid specimens from five patients, subsequent abscess culture was obtained from only one of these individuals. In this single instance the CSF growth was identical to abscess flora. Reliance on cerebrospinal fluid findings for brain abscess diagnosis was often very misleading, and CSF gram stains and cultures were generally unrewarding in the absence of an associated meningitis.

In addition to the unreliability of CSF analysis, lumbar puncture itself was implicated in the subsequent deaths of eight patients (Table 7). Each of these individuals was neurologically stable prior to spinal tap, many having had abscess symptoms for weeks. Deterioration and death ensued after tapping. Two patients had multiple abscesses and would not have been expected to survive, while another who underwent abscess drainage in addition to lumbar puncture has been included under surgical deaths. The deaths of five individuals with solitary abscesses can be directly attributed to lumbar puncture, an 8% mortality for this diagnostic procedure.

Patients Comatose at Surgery

Patient survival was most closely correlated with the preoperative level of consciousness (Table 8). All etiological abscess groups are represented in the Grade IV category. Seven of the eight patients who died because of poor neurological status entered University Hospitals either "fully alert" or

TABLE 7
Analysis of deaths precipitated by lumbar puncture

<table>
<thead>
<tr>
<th>Case No.</th>
<th>Time of Death After Lumbar Puncture (hrs)</th>
<th>Neurologic Status Before Lumbar Puncture</th>
<th>Mode of Death</th>
</tr>
</thead>
<tbody>
<tr>
<td>1*</td>
<td>8–12</td>
<td>alert</td>
<td>herniation</td>
</tr>
<tr>
<td>2</td>
<td>12</td>
<td>alert</td>
<td>herniation</td>
</tr>
<tr>
<td>3</td>
<td>12</td>
<td>alert</td>
<td>herniation</td>
</tr>
<tr>
<td>4</td>
<td>15</td>
<td>alert</td>
<td>herniation</td>
</tr>
<tr>
<td>5*</td>
<td>15</td>
<td>drowsy</td>
<td>herniation</td>
</tr>
<tr>
<td>6</td>
<td>21</td>
<td>drowsy</td>
<td>herniation</td>
</tr>
<tr>
<td>7†</td>
<td>36</td>
<td>pain response only</td>
<td>herniation</td>
</tr>
<tr>
<td>8</td>
<td>36</td>
<td>alert</td>
<td>not indicated</td>
</tr>
</tbody>
</table>

* Multiple abscesses.
† Operative death.
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### TABLE 8
Relation of preoperative neurological state to surgical mortality in 61 patients with operable, single brain abscesses

<table>
<thead>
<tr>
<th>Responsiveness</th>
<th>Alive</th>
<th>Dead</th>
<th>Total Cases</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No.</td>
<td>%</td>
<td></td>
</tr>
<tr>
<td>Grade I (fully alert)</td>
<td>15</td>
<td>4</td>
<td>19</td>
</tr>
<tr>
<td>Grade II (drowsy)</td>
<td>19</td>
<td>5</td>
<td>24</td>
</tr>
<tr>
<td>Grade III (respond to pain only)</td>
<td>5</td>
<td>4</td>
<td>9</td>
</tr>
<tr>
<td>Grade IV (no response to pain)</td>
<td>1</td>
<td>8</td>
<td>9</td>
</tr>
</tbody>
</table>

"drowsy," while one entered only "responsive to painful stimuli." These eight individuals underwent neurological deterioration to an irretrievable degree while undergoing evaluation. The only totally comatose individual to survive was a 7-year-old boy with a brain abscess that recurred 3 months after a drainage procedure. The child was brought to the emergency room complaining of headache and while there became unresponsive. The recurrent abscess was quickly aspirated via the previously placed burr hole and the child eventually recovered.

### Evaluation of Surgical Therapy

Sixteen individuals died because of inadequate diagnosis or before surgery was undertaken. Two children, hospitalized for 5 and 8 days respectively and correctly diagnosed upon admission as having a brain abscess, died before surgical therapy was undertaken. Seventeen patients, in poor (Grade IV) neurological status or with multiple inoperable lesions, were unlikely to survive whatever the form of surgery. There were, then, 53 patients on whom to judge the effects of surgery. These patients with solitary brain abscesses were operated on while in retrievable neurological condition. Forty patients lived and 13 died, giving an adjusted surgical mortality of 25% (Table 9).

In abscesses successfully located the mortality rate ranged from a low of 18% with multiple forms of therapy to a high of 33% secondary to aspiration. Only six patients were treated by aspiration alone, and this group is too small for meaningful analysis. Approximately equal numbers of patients underwent drainage and excision, and the mortality associated with these procedures was essentially the same. The preoperative neurological status itself influenced the mode of surgical therapy. Abscess excision via formal craniotomy was more likely to be undertaken when patients were in better neurological condition. Abscesses in these individuals were often well encapsulated, less fulminating in their course, and more suitable for excision. Simpler methods of treatment such as aspiration or drainage were preferred for less responsive patients.

Table 10 lists postoperative complications in the 13 neurologically retrievable patients who died after surgery for their solitary brain abscess. The source of the abscess in the 13 fatalities was as follows:

- metastasis (otherwise normal patient) 6
- metastasis (congenital heart disease) 4
- sinus or mastoid infection 1
- trauma 2

Three of the four patients with abscesses due to congenital heart defects died because of excessive intracranial bleeding.

### TABLE 9
Relation of surgical treatment to mortality in 53 neurologically retrievable patients (Grades I, II, III) with a solitary brain abscess

<table>
<thead>
<tr>
<th>Treatment</th>
<th>No. of Cases</th>
<th>Lived No.</th>
<th>Died No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>aspiration drainage</td>
<td>6</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>excision</td>
<td>16</td>
<td>13</td>
<td>3</td>
</tr>
<tr>
<td>multiple method</td>
<td>18</td>
<td>14</td>
<td>4</td>
</tr>
<tr>
<td>abscess missed at surgery</td>
<td>11</td>
<td>9</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>Total</td>
<td>53</td>
<td>40</td>
<td>13</td>
</tr>
</tbody>
</table>

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TABLE 10
Complications among 13 patients who died following surgery

<table>
<thead>
<tr>
<th>Complicating Condition</th>
<th>Types of Surgical Therapy</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Aspiration</td>
<td>Drainage</td>
</tr>
<tr>
<td>cerebritis/meningitis</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>recurrent abscess</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>excessive local edema</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>excessive bleeding at operative site</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>uncertain</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>abscesses missed (brain biopsies)</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Total</td>
<td>2</td>
<td>3</td>
</tr>
</tbody>
</table>

Discussion

Nature of the Lesion

In this series of 86 patients, 8% presented multiple abscesses. Other authors have reported a 5% to 15% incidence of multiple brain abscesses. All of our patients with multiple abscesses died, and this has been the usual experience. In one series reporting an 85% mortality with multiple brain abscesses, three patients lived as several abscesses occurred and were treated over a 2- to 4-month period; this phenomenon is different from that of simultaneous multiple abscess occurrence. Both of our patients with pontine abscesses died as did the patient with a brain-stem abscess in Gurdjian’s recent report. In any series of intracerebral abscesses there appears to be an inherent irreducible mortality of approximately 10%. Patients having simultaneous, multiple hemispheral lesions or brain-stem abscesses are quite unlikely to survive.

Diagnostic Difficulties

As Table 3 indicates, metastatic brain abscesses in otherwise normal individuals were hardest to diagnose. Eighteen of 33 such patients in this series died, and in seven the abscess was discovered at postmortem examination. All told, 15 of 46 deaths could be attributed to diagnostic failure or delay. More frequent consideration of brain abscess is necessary when evaluating patients manifesting cerebral signs and symptoms. Abscess may possibly be distinguished from other space-occupying intracerebral lesions if significance is attached to a history of recent infection and a high ESR is noted. If clearcut evidence of infection such as fever or elevation of peripheral blood WBC or PMN is required, the diagnosis will often be missed.

While CSF analysis may lead to the diagnosis of brain abscess, our experience in this regard was not reassuring. Approximately one third of the patients had 0 to 10 WBC/mm$^3$ of CSF and three quarters had normal CSF glucose. These findings were similar to those of Kiser and Kendig who observed 0 to 10 WBC/mm$^3$ CSF in 15 of 68 patients (22%) and normal CSF glucose in 32 of 36 individuals (89%). Cerebrospinal fluid gram stain and cultures were unrewarding in abscess diagnosis or treatment. Virtually all gram stains were negative and cultures sterile in the absence of a frank meningitic component to the abscess. When positive, gram stains had poor correlation to bacteria actually cultured from the brain abscess.

Table 5 indicates that brain scans, angiography, ventriculography, and electroencephalography localized a brain abscess with a high degree of accuracy and with lower mortality than did lumbar puncture. Five of 62 patients (8%) died as a direct result of lumbar puncture. Garfield, in reviewing 200 patients with intracerebral abscess, reported that 140 individuals underwent lumbar puncture and 41 had subsequent related neurological deterioration, many patients dying secondary to the spinal tap.

High mortality, lack of localizing information, misleading laboratory results, and high incidence of spinal fluid sterility make lumbar puncture a poor diagnostic test for a
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TABLE 11
Relation of mortality to preoperative neurological status in four series of brain abscess cases

<table>
<thead>
<tr>
<th>Clinical Status</th>
<th>Newlands (80 Cases)</th>
<th>Kerr, et al. (47 Cases)</th>
<th>Garfield (200 Cases)</th>
<th>Carey, et al. (86 Cases)</th>
</tr>
</thead>
<tbody>
<tr>
<td>alert</td>
<td>11%</td>
<td>0%</td>
<td>18%</td>
<td>21%</td>
</tr>
<tr>
<td>drowsy</td>
<td>29%</td>
<td>17%</td>
<td>32%</td>
<td>21%</td>
</tr>
<tr>
<td>responsive to pain</td>
<td>50%</td>
<td>--</td>
<td>65%</td>
<td>--</td>
</tr>
<tr>
<td>not responsive to pain</td>
<td>50%</td>
<td>60%</td>
<td>72%</td>
<td>89%</td>
</tr>
</tbody>
</table>

brain abscess. It is recommended that when a brain abscess is suspected, lumbar puncture should be withheld. High doses of broad spectrum antibiotics should be started, as recommended for the initial treatment of meningitis, while more definitive diagnostic and localizing tests are undertaken (brain scan, EEG, and angiography). Currently, many authorities feel that ampicillin and kanamycin are the antimicrobial agents of choice.19,20,22

Underestimation of Brain Abscess

Two patients with fever, headache, and focal neurological findings were suspected of having a brain abscess. They lapsed into coma and died before neurosurgical intervention was undertaken.

Brain abscess is not a neurosurgical emergency as long as the patient remains alert and without severe neurological deficits. An intracerebral abscess may, however, act as a rapidly expanding intracranial mass and compress midbrain and brain-stem structures leading to coma and death. In the present series, postmortem examination was made 29 times. Twenty-five deaths were due to abscess mass and uncal herniation leading to midbrain compression. Only four patients died because of abscess rupture into the ventricular system. When a brain abscess is suspected, therefore, close neurological observation is imperative while the patient is being treated with antibiotics and undergoing diagnostic tests. Any deterioration in the level of consciousness or significant increase in neurological deficit demands immediate neurosurgical attention.

Patients Comatose at Surgery

Table 11 demonstrates a clear correlation between patient survival and the preoperative neurological status as measured by the level of alertness. These observations are in agreement with those of many other authors.8,14,21

Clinical measurements of alertness reflect midbrain integrity. Increasing abscess mass and associated edema compromise midbrain structures and lead to drowsiness, coma, and eventual death. Patients with intact midbrain structures at the time of surgical intervention are more likely to survive than those manifesting midbrain or brain-stem dysfunction.

Surgical Treatment

Several techniques have evolved for the treatment of brain abscess. Drainage procedures were used earliest.5,5,12,17,18 In 1926 Dandy4 proposed simple aspiration of the abscess via a burr hole. Abscess excision, first advocated by Clovis Vincent, et al.,23 in the mid 1930’s, has many advocates.1,14,16 Whether brain abscesses are best treated by aspiration, drainage, or excision has been the recurrent theme of neurosurgical papers. In many reports1,13,14 a particular form of therapy is favored and extensively used, making it difficult to compare various forms of surgical therapy.

We have used all forms of treatment, and abscess drainage may therefore be compared with excision in a small group of 34 theoretically curable patients with solitary brain abscesses. Table 9 indicates that abscess drainage was associated with approximately the same mortality as excision (19% vs 22%). Drainage, however, was used in sicker individuals. Six of 15 patients who underwent drainage were in neurological Grade III (responsive to painful stimuli only) at the time of operation. Three abscesses recurred after drainage, but only one subsequently proved fatal.

Approximately one in five patients who underwent excision died, but postoperatively...
these patients were generally in better condition than those having drainage. Eighteen of 19 patients having excision were neurologically Grades I and II at surgery. A single abscess recurred after excision, but a fatality was prevented by re-excision of the lesion.

While the mortality rate was essentially the same for both forms of treatment, a slight edge may be given to abscess drainage as a form of therapy since it was employed, with no increased mortality, in more neurologically decompensated patients.

Gurdjian has indicated that aspiration with antibiotic instillation was as effective as excision. In 22 cases where excision was done, two patients died (9% mortality), and in 21 cases treated by tapping and antibiotic instillation three patients died (14% mortality).

The exact form of therapy, whether by abscess drainage, excision, or aspiration may not be as important as the fact that some pressure-relieving surgical procedure has been undertaken before irreversible brainstem damage has occurred secondary to increasing abscess mass.

Permanent postoperative seizures developed in only one of 13 patients who underwent abscess drainage. Six of 14 individuals whose abscesses were excised developed a long-term seizure diathesis (abscess locations: 2 frontal, 2 parietal, 1 frontotemporal, 1 temporal). Our data indicate that drainage has a lower postoperative long-term seizure incidence than excision despite the presence of a retained abscess capsule. Retained capsules may represent less of an epileptogenic hazard than gliosis following the local trauma of excision.

Deaths Following Surgery

Table 10 indicates that unsatisfactory surgical results were related to such technical failures as inability to locate the abscess or to complications such as cerebritis, edema, and excessive bleeding at the abscess site. Three out of the four patients who died because of this latter complication had abscesses secondary to congenital heart defects. In addition to having a large abscess, these individuals may often be in precarious cardiac status and have hard-to-treat coagulopathies. Because drainage procedures are rapid, simple, and relatively bloodless, this form of therapy is particularly recommended for the treatment of these abscesses.

Technique of Abscess Drainage

The following technique of abscess drainage is used at the University of Minnesota Hospitals. A burr hole is placed at the suspected site and a small dural opening made. A 13-gauge needle is inserted into the abscess, with care taken not to pass beyond into the ventricle. Purulent material is collected in a syringe to avoid soil ing the operative area. A specimen of pus is sent to the laboratory immediately for gram stain and aerobic, anaerobic, and fungal culture. After the initial few cubic centimeters of purulent material have been collected, the brain needle is occluded, retaining pus within the abscess cavity and preventing its collapse. The brain needle is then withdrawn and an appropriate rubber catheter passed along the needle track into the still partially filled abscess cavity. Large diameter catheters are utilized for viscous pus and smaller bore catheters for thinner drainage material.

After the catheter has been properly placed in the abscess cavity it is held in place by an assistant while the skin incision is closed. The catheter is then fixed by suturing it to the skin. A safety pin, passed at right angles through the catheter at skin level, prevents it from being inadvertently advanced further into the brain. The drainage tube is cut off \( \frac{1}{8} \) cm above the skin and the abscess cavity is irrigated through the tube with an antibiotic solution (aqueous penicillin 1000 units/ml and streptomycin 1 mg/ml or bacitracin 500 units/ml). At this point thorotrast or micropaque barium may be instilled into the abscess for future x-ray visualization. When the head dressing is applied, “four by four” dressings are built up around the protruding tube so no pressure is placed upon it.

Daily dressing changes and irrigation are carried out. Returns from the abscess are usually minimal after the initial drainage, but the rubber tube is left in place as long as any drainage ensues. After drainage has ceased the tube is slowly withdrawn, days to weeks being required for removal. Follow-up contrast studies are usually obtained.
Experience with brain abscesses

Summary
Of 86 patients with brain abscesses hospitalized at the University of Minnesota Hospitals (1946–65), 46 died. Reasons for death, usefulness of various diagnostic tests, and efficacy of surgical therapy have been analyzed and evaluated as follows:

1. Multiple simultaneous or brain-stem abscesses accounted for 10% of deaths.
2. Approximately one third of the deaths were caused by missed or delayed diagnosis. Evidence of infection may be minimal in patients with brain abscess. Lumbar puncture often gave misleading information and had an associated 8% mortality.
3. Brain scan and angiography were the best diagnostic tools.
4. Patient survival was correlated most directly with a satisfactory preoperative neurological status.
5. The mortality associated with drainage was 19% and that with excision 22%. The most important factor influencing survival was relief of increased intracranial pressure by some form of surgery while the patient was neurologically alert.

References

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