THE SURGICAL MANAGEMENT OF CEREBRITIS COMPLICATING PENETRATING WOUNDS OF THE BRAIN*

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One of the most disheartening complications of penetrating wounds of the brain is the development of cerebritis which is commonly accompanied by formation of a cerebral fungus. Experiences in World War II and in the Korean War have shown that earliest possible definitive neurosurgical care of patients with penetrating wounds of the brain should be considered the largest single factor in the prevention of such cerebritis. The employment in Korea of mobile neurosurgical teams close to the line was associated with a reduction of meningocerebral infection from 41 per cent to less than 1 per cent.

Cerebritis as a sequel of penetrating wounds of the brain may be induced by delayed surgical intervention, or by the retention of debris, devitalized tissue and bone fragments. Improper wound closure or faulty healing may then lead to the formation of a cerebral fungus.¹,²,³,⁷,⁹,¹⁰ Though there are many proposed regimens for handling cerebral fungi,⁴,⁶,⁸,¹⁰,¹¹ the management of frank cerebritis has seldom been approached surgically. It is the purpose of this communication to propose a method of "open" surgical treatment of fulminating, fungating cerebritis which is based on the experiences of one of us in the Okinawa Campaign (1945) and on joint experiences in the Korean conflict. The employment of this method has been associated with a reduction of mortality and morbidity and has been an essential factor in lessening the ultimate neurological deficit.

METHOD OF TREATMENT

Prior to operation antibiotics were administered in accordance with culture and sensitivity studies. Such therapy is maintained for 10 days after closure or until all evidence of infection has subsided. The empirical administration of penicillin 600,000 units b.i.d. and of streptomycin 1 gm.

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b.i.d. has been found advantageous whenever facilities for culture and sensitivity determinations are not available.

1. Initial Resection. At operation radical extracerebral debridement with wide resection of the involved portions of the scalp, bone and dura mater is performed. This leads to complete exposure of the fungating mass of necrotic, shaggy cerebrum which is usually surrounded by tense, edematous, but apparently viable brain. The entire fungating mass, or area of cerebritis, is then resected until healthy though sometimes still edematous brain tissue is encountered. Digital palpation will help to determine the tissue consistency and to assure removal of all intracerebral bone fragments. Meningocortical adhesions around the periphery of the wound are divided and resected, allowing the brain to retract within the cranium. The danger of destroying natural barriers to the passage of infection is greatly outweighed by the advantage of direct examination of the subdural space for hematoma or hydroma. Retention in the subdural space of a hematoma, which may also harbor infectious organisms, may be conducive to the continued herniation of cerebral tissue. Upon completion of the initial resection, lumbar puncture is performed to facilitate further retraction of the cerebrum. Withdrawal of 60 to 80 cc. of fluid is usually sufficient to establish a desirable degree of retraction.

The new brain surface is then thoroughly irrigated with saline solution and covered with a square of pure, fine-mesh, autoclaved silk cloth soaked in saline or penicillin solution (5000 units/cc.). The moist, non-irritating piece of silk is covered with strips of vaseline gauze. To protect the brain surface further, gauze fluffs are incorporated in the dressing which is held together by a 5-yard gauze roll.

2. Interval Care. The wound is redressed, inspected and irrigated 4 hours after the initial resection and again 8 hours later. The frequency of dressings thereafter is determined by the appearance of the new cerebral surface. So as to keep this surface free from any appreciable accumulation of the products of progressing necrosis, it is usually necessary to repeat the irrigations every 8 to 12 hours.

Each dressing is carried out with the same precautions as those used in the operating room. The wound is exposed, the scalp edges are cleaned with merthiolate and the entire field is draped with sterile towels. Reshaving may be necessary every 2 to 3 days. The surface of the brain is thoroughly irrigated with a continuous stream of saline from an aseptic syringe. Often, 8 to 12 hours after the initial resection, the brain may begin to protrude above the surface of the skull, forming a true cerebral fungus. This is not disastrous, the causative edema being less damaging if the brain is allowed to expand than if it is confined within the cranium by some artificial means. Excessive herniation may have to be controlled by lumbar punctures judiciously repeated whenever the progression of herniation is rapid.* In

* Continuous drainage by means of a polyethylene catheter inserted into the lumbar space may be a practical way of keeping the intracranial pressure low. The employment of a drainage bottle set at an appropriate level makes it possible to predetermine the intracranial pressure.
such cases it may be necessary to separate the scalp edges bluntly from the underlying cortical surface and to irrigate the subdural space.

Duration of the open treatment depends on the appearance of the cerebral surface and on the clinical response of the patient. As infection subsides and debris and exudate are washed away, the surface of the brain assumes a pinkish-gray appearance and takes on a firm consistency; this is usually accompanied by cessation of progressive fungation, indicating that the infection has subsided and that it may be safe to perform secondary closure.

3. Final Closure. The patient is prepared for secondary craniotomy. The edges of all layers of the scalp are freshened. The cerebral surface is cleanly resected by sharp dissection, employing silver clips for hemostasis. The dural edges are freed from the cortex and the dural defect is repaired with a fascia lata graft which is secured with interrupted sutures of fine silk. The scalp is closed in layers without tension, using whatever plastic procedure may be feasible in the individual case. Cranioplasty is deferred for at least 12 months.

REPRESENTATIVE CASES

Case 1. An 18-year-old American soldier sustained a penetrating missile wound of the left frontal lobe of the brain on Oct. 9, 1950 while in combat in Korea. Three days later, at a Station Hospital, the wound was debrided and dural closure effected.

Examination. On admission to the Neurosurgical Center at Tokyo Army Hospital on Oct. 13, 1950, the patient was stuporous and febrile. Positive neurological findings were mild papilledema, right facial weakness, mild weakness of the right arm and leg, and hyperactive deep tendon reflexes on the right. The neck was moderately stiff. Inspection of the sutured laceration in the left frontal area revealed a small amount of purulent discharge.

Conservative treatment with irrigation of the wound was of no avail and it was thought that there existed an underlying abscess or cerebritis. X-ray studies did not reveal any retained bone or metallic fragments.

1st Operation. The old wound was reopened, revealing a tight, bulging dural graft with suppurative material exuding from beneath its edges. The surface of the brain was shaggy, necrotic, edematous and grossly infected. The entire area of cerebritis was resected. A direct communication with the anterior horn of the left lateral ventricle was noted, and a piece of gelfoam was inserted in the opening. The wound was left open, dressed with saline-soaked silk and irrigated at frequent intervals as described above.

Course. Herniation of the brain was controlled with lumbar puncture. Ten days later the wound appeared clean, the resected bed was firm and there had been no progressive herniation of the brain after a 24-hour period without lumbar puncture. Simultaneously with the decrease in rate of protrusion of the brain surface, there was marked clearing of the patient’s mental status which in the early phases of his treatment had been one of confusion and extreme irritability.

2nd Operation. The presenting surface of the brain was further resected and fascial closure was effected.

Course. Postoperatively, a minimal separation of the scalp in the center of the wound was noted. This healed spontaneously without recurrence of infection. One month later the patient was evacuated to the Zone of Interior. The scalp was well
healed and showed normal pulsations. The neurological deficit that was noted on
admission was decreased slightly.

A follow-up letter, received 2 years after the initial injury, reveals that this
patient does not have any residual neurological deficit. He has had two epileptic
seizures. He also complains of intermittent headaches.

Case 2. An 18-year-old American soldier sustained a penetrating missile wound
of the left parietal lobe of the brain on Sept. 15, 1950 while in combat in Korea. The
record revealed that a craniectomy had been performed at a forward surgical instal-
lation with "evacuation of clots, debridement of cortex and removal of depressed
bone fragments." Two days later, at a Station Hospital, the wound was revised and
the dural defect was closed.

Examination. On admission to the Neurosurgical Center at Tokyo Army Hos-
pital 7 days later, the patient appeared lethargic, but could be roused. He had a
mixed aphasia. There was marked hemiparesis on the right with hyperactive deep
tendon reflexes in the right arm and leg. X-ray studies of the skull revealed numer-
ous retained bone fragments within the cerebral substance.

1st Operation. The patient was subjected to reoperation with removal of an
extensive subdural hematoma, retained bone fragments and frank pus at the depth
of the missile tract.

Course. Seven days later the wound began to separate. After 11 days a large
cerebral fungus presented on the surface.

2nd Operation. The fungus and the surrounding cerebritic cortex were resected.

Course. Open therapy was instituted. Three days later, the surface of the brain
appeared clean and had taken on a firm consistency. There was no increasing pro-
trusion of brain substance.

3rd Operation. The presenting cerebral surface was again resected and the dural
defect was closed with a fascia lata graft. The scalp was closed without drainage.

Course. Postoperatively the patient fared well except for slight separation of
the skin edges without evidence of infection. This healed spontaneously. At time
of evacuation to the Zone of Interior 2 months later, the scalp was well healed. The
patient had regained considerable motor power on the right side. A right upper
quadrandal field defect persisted. There was minimal residual dysphasia.

A follow-up letter, received 26 months after the initial injury, reveals that there
has been complete recovery from the neurological deficit. The patient is on pheno-
barbital medication, but has had one seizure. He also reported that cranioplasty had
been postponed for 15 months because of intermittent drainage from the superficial
layers of the scalp. There has been no infection since then. Following discharge from
the Army in October 1952, the patient has been employed in the Vehicle Storage
Division of an Air Force Base.

RESULTS

The early results of this open method of treatment of fulminating, fungating cerebritis have been encouraging (Table 1). In 17 cases of cere-
britis complicating penetrating wounds of the brain, there were 3 deaths.
Two patients died after closure (No. 8 and No. 16) while 1 died during open
therapy (No. 5). One of these 3 patients (No. 16) had demonstrated an ex-
tremely extensive neurological deficit on admission, suggesting decerebra-
tion. This patient had had a complete transection of the sagittal sinus just
proximal to the torcular Herophili with thrombosis of the ends of the proximal and distal segments. The fungus bed appeared to be clean at time of closure and death may not have to be interpreted in this case as a failure of the proposed method.

In patient No. 8 death was preceded by hypothermia, hypotension, bradycardia, and gastric distention suggesting progressive cerebritis involving the hypothalamus. In case No. 5 death was caused by massive cerebritis involving the entire right cerebral hemisphere, associated with ventriculitis. The latter was present at time of institution of open therapy.

The remaining 14 patients were evacuated to the Zone of Interior with healed wounds and without evidence of residual superficial or central nervous system infection. In 10 patients there was persistent superficial scalp infection for a short time after closure, but these had all cleared prior to evacuation. Three patients showed transient clinical meningitis after closure. This responded with complete subsidence to antibiotic therapy. In 1 instance (No. 1) closure was performed too early and open therapy had to be reinstituted before the desired result could be obtained. In no case was there evidence of abscess formation prior to evacuation. There was no increase in the neurological deficit in any of the patients, but all 14 showed definite improvement in the neurological status following completion of open therapy.

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**TABLE 1**

<table>
<thead>
<tr>
<th>Pt. No.</th>
<th>Wound Location</th>
<th>Ventricle Involved</th>
<th>Duration Open Treatment</th>
<th>Meningitis After Treatment</th>
<th>Superficial Infection After Treatment</th>
<th>Results</th>
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<tbody>
<tr>
<td>1</td>
<td>Rt. parietal</td>
<td>Yes</td>
<td>48 days</td>
<td>No</td>
<td>No</td>
<td>Cured</td>
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<td>2</td>
<td>Rt. parietal</td>
<td>Yes</td>
<td>36 days</td>
<td>No</td>
<td>Yes</td>
<td>Imp.</td>
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<tr>
<td>3*</td>
<td>Lt. frontal</td>
<td>Yes</td>
<td>10 days</td>
<td>No</td>
<td>Yes</td>
<td>Imp.</td>
</tr>
<tr>
<td>4</td>
<td>Lt. frontotemporal-parietal</td>
<td>Yes</td>
<td>82 days</td>
<td>No</td>
<td>Yes</td>
<td>Cured</td>
</tr>
<tr>
<td>5</td>
<td>Rt. temporoparietal</td>
<td>Yes</td>
<td>9 days</td>
<td>No</td>
<td>Yes</td>
<td>Cured</td>
</tr>
<tr>
<td>6</td>
<td>Lt. temporoparietal</td>
<td>No</td>
<td>30 days</td>
<td>No</td>
<td>No</td>
<td>Imp.</td>
</tr>
<tr>
<td>7</td>
<td>Rt. frontal</td>
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<td>30 days</td>
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<td>No</td>
<td>Cured</td>
</tr>
<tr>
<td>8</td>
<td>Rt. parietal</td>
<td>Yes</td>
<td>12 days</td>
<td>No</td>
<td>Yes</td>
<td>Death</td>
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<td>9</td>
<td>Rt. frontoparietal</td>
<td>Yes</td>
<td>6 days</td>
<td>No</td>
<td>Yes</td>
<td>Cured</td>
</tr>
<tr>
<td>10</td>
<td>Rt. parietal</td>
<td>Yes</td>
<td>7 days</td>
<td>No</td>
<td>Yes</td>
<td>Imp.</td>
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<td>11†</td>
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<td>3 days</td>
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<td>Rt. occipitoparietal</td>
<td>Yes</td>
<td>8 days</td>
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</tr>
<tr>
<td>13</td>
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<td>14</td>
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<td>Imp.</td>
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<td>38 days</td>
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<td>16</td>
<td>Bi-occipital</td>
<td>Yes</td>
<td>4 days</td>
<td>Yes</td>
<td>No</td>
<td>Death</td>
</tr>
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<td>17</td>
<td>Rt. frontal</td>
<td>No</td>
<td>6 days</td>
<td>No</td>
<td>No</td>
<td>Cured Imp.</td>
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* Representative Case 1 (see text).
† Representative Case 2 (see text).
DISCUSSION

The method of choice in the management of penetrating missile wounds of the brain is earliest possible definitive neurosurgical intervention with radical debridement, removal of all devitalized tissue and primary closure of the dura mater and scalp. The early phase of the Korean War presented the unfortunate opportunity to see patients with fulminating, fungating cerebritis as sequel of untreated, or inadequately treated missile wounds of the brain. Although all patients in this series had received adequate dosages of antibiotics from the very beginning, cerebritis developed in association with the prolonged retention within the cranial cavity of devitalized tissue, clots and bone fragments. The marked increase in the neurological deficit and the high mortality in those who were subjected to surgical resection of the area of cerebritis and primary closure, led us to adopt the "open" method of treatment which is described in this communication. Its employment, however, has been reserved for previously untreated missile wounds with fulminating, fungating cerebritis and for those patients in whom such cerebritis had developed following inadequate debridement and closure.

Of the 15 patients in the present series who had been operated on prior to institution of open therapy, 13 presented an infected fungus or a draining sinus which led through small openings in the scalp and dura mater to a large underlying area of cerebritis. The remaining 2 were operated on because of bulging flap and other signs of increased intracranial pressure. When the suspected cerebritis was found, it was resected and subjected to open therapy.

Two patients in the series had accompanying lacerations of the sagittal sinus. In 1 (No. 16) the laceration was anatomically complete with thrombosis of the distal and proximal openings into the sinus. In the other (No. 13) there was laceration of the sinus with thrombosis proximal to the tear. The thrombus was evacuated and the laceration was repaired by primary suture and gelfoam.

The presence of ventricular penetration may complicate an existing cerebritis or fungus, but should not offer a deterrent to the institution of open therapy. Ten patients in this series presented ventricular perforations at the time of the first operation at the Neurosurgical Center at the Tokyo Army Hospital.

The duration of open treatment varied from 3 to 82 days with an overall average of 24 days. Though early closure is most desirable, prolonged open therapy is felt to be justified by ultimate cure of an otherwise hopeless situation.

Definitive resection at time of creation of the open wound is advantageous though not always feasible. In some instances further demarcation of non-viable brain necessitates interval resection. In this series 7 patients required from one to three interval resections. In 4 patients, from one to four minor procedures for scalp closure were necessitated by failure of scalp healing without recurrence of fungus or cerebritis. In all patients except in
the one who died during open therapy (No. 5) closure was completed prior to evacuation to the Zone of Interior.

SUMMARY

1. A method of open surgical treatment of fulminating, fungating cerebritis is proposed.

2. Two representative cases are presented in detail and the results of 17 patients so treated are discussed.

REFERENCES

5. Evans, J. P. Personal communication.