PARASAGITTAL MENINGIOMAS OF THE LONGITUDINAL SINUS AND FALX

JAMES C. WHITE, M.D., ROBERT S. SCHWAB, M.D., AND IHSAN SAHINALP, M.D.

Neurosurgical and Neurological Services, Massachusetts General Hospital, and Departments of Surgery and Neurology, Harvard Medical School, Boston, Massachusetts

(Received for publication July 29, 1958)

The neurological and surgical aspects of meningiomas of the falx and parasagittal region have been described with such clarity and detail, notably by Cushing and Eisenhardt (58 cases), Elsberg (25), and more recently by Grant (128), Petit-Dutaillis and Pertuiset (12), Hoessly and Olivecrona (280), and Simpson (Cairns' series of 90) that there is no need to discuss further examples of these interesting tumours in a similar general way. Our purpose in writing this account of a small series of 25 personally treated and carefully followed cases is to record additional statistics on their clinical course and to stress certain points that have not been emphasized in these outstanding reports nor by others to our knowledge. It has been possible to follow 20 of our patients for periods ranging from 3 to 20 years after their initial surgery. One succumbed at the first operation, 1 has been lost track of, and 3 others have been operated upon only within the last 20 months.

Especial features that can be further discussed with profit include the following:

1) The low rate of postoperative mortality and morbidity made possible by modern surgical techniques.

2) The probability of prolonged useful survival.

3) The predominant tendency of meningeal tumours in this region to induce epileptic seizures and their response to surgical removal of the neoplastic focus.

4) Electroencephalographic findings before and after surgery.

5) Plans for further improvement in surgical technique.

The meningiomas in this series varied in size up to 250 gm. Although some recurred a number of times, only 1 with a relatively early recurrence showed histological evidence of malignant change. Three were of the hyperostosing variety, but none developed massive thickening of the cranial vault.

1. Postoperative Mortality and Morbidity Rates. In view of the previous exhaustive statistics on surgical mortality, this requires no comments beyond the fact that its rate continues to fall. Available figures on this score reported by Cushing and Eisenhardt, Grant, Petit-Dutaillis and Pertuiset.
and Hoessly and Olivecrona\textsuperscript{7} are compared with the present series in Table 1. Nothing can speak more eloquently for the masterly quality of Cushing's technique than the fact that he was able to carry such a large proportion of his patients through these difficult operations over the years when transfusion was seldom used. In addition one must remember he had the advantages of electrocoagulation only during his last 5 years and that Gelfoam, thrombin solution, and hypotensive drugs have all been developed since his death. Grant\textsuperscript{6} has recently given an excellent account of the steps in surgical resection of these difficult tumours that are of vital importance in lowering operative mortality and postoperative complications. To-day when the brain is tense or the tumour is unusually vascular, surgical removal can be carried out with increased safety under hypothermia. Sedzimir and Dundee\textsuperscript{18} have stressed its advantages and we have found it to be of inestimable value in removing a dumbbell-shaped tumour arising from the deep central portion of the falx (see below). Of our 2 deaths the first was a true surgical casualty caused by excessive loss of blood; the second (in Patient 8) re-

**TABLE 1**

Mortality statistics: Relation to position of parasagittal meningiomas

<table>
<thead>
<tr>
<th>Series</th>
<th>Tumour Attachment</th>
<th>Total Hospital Mortality</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>To Longitudinal Sinus</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Ant. Third</td>
<td>Mid. Third</td>
</tr>
<tr>
<td>Cushing &amp; Eisenhardt\textsuperscript{**}</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Deaths</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>No. of patients</td>
<td>13</td>
<td>32</td>
</tr>
<tr>
<td>Mortality</td>
<td>15.4%</td>
<td>12.5%</td>
</tr>
<tr>
<td>Hoessly &amp; Olivecrona\textsuperscript{7}</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Deaths</td>
<td>3</td>
<td>14</td>
</tr>
<tr>
<td>No. of patients</td>
<td>56</td>
<td>109</td>
</tr>
<tr>
<td>Mortality</td>
<td>5.4%</td>
<td>12.8%</td>
</tr>
<tr>
<td>Present series</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>Deaths</td>
<td>6</td>
<td>13</td>
</tr>
<tr>
<td>No. of patients</td>
<td>13</td>
<td></td>
</tr>
<tr>
<td>Mortality</td>
<td>0%</td>
<td>15.4%</td>
</tr>
</tbody>
</table>

Additional recent statistics of mortality have been reported by:

- **Grant\textsuperscript{6}**: 128 operations with 19 deaths:
  - Case mortality 18%
  - Operative mortality 14%

- **Petit-Dutaillis & Pertuiset\textsuperscript{14,16}**: 12 patients with 2 deaths:
  - Case mortality 16.6%
  - Operative mortality 13%

* These statistics of Cushing and Eisenhardt are presented somewhat differently from their book, in which the parasagittal and falx meningiomas are recorded separately.
sulted from sepsis 3 months after the fourth operation for recurrence, following failure of the heavily irradiated scalp to heal.

Examination of Table 2 brings out the serious risk of incurring lasting cortical injury in dealing with tumours attached to the central portion of the falx. In this situation it is difficult to avoid trauma to the cortex that controls movement and sensation in the lower extremity, especially when the meningioma has deeply indented the medial surface of the hemisphere. In

### TABLE 2

*Residual postoperative cerebral damage in 24 survivors*

<table>
<thead>
<tr>
<th>Position of Meningioma</th>
<th>No. of Cases</th>
<th>Hemiplegia</th>
<th>Hemi-paresis</th>
<th>Sensory Deficit</th>
<th>Dysphasia</th>
<th>Homonymous Hemianopsia</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anterior third longitudinal sinus</td>
<td>6</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Central third longitudinal sinus</td>
<td>12</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>3*</td>
</tr>
<tr>
<td>Posterior third longitudinal sinus</td>
<td>4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Falx (central)</td>
<td>2</td>
<td>1†</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Antedating operation in 2.
† Of brief duration with complete recovery.

Patient 19 the tumour had burrowed completely through so that its outer portion presented as an island in the region of the postcentral cortex and supramarginal gyrus on the dominant side. It was therefore impossible to avoid increasing the pre-existing sensory-motor and speech defects.

Another factor that may lead to spastic paralysis of the lower extremity is the necessity of sacrificing the Rolandoic vein to gain exposure to the underlying meningioma. Our experience here has shown that the resulting interference with venous drainage of the upper portion of the central strip in 6 cases has resulted in no neurological damage in 1, 2 transitory hemiplegias which cleared rapidly and completely, and permanent spasticity and weakness of varying degree in 3 others. In one of the latter every effort had been made to spare this important vessel which ran along the posterior edge of a precentral tumour. Nevertheless it must have thrombosed, as the patient has remained hemiplegic with a significant parietal sensory defect since her discharge in 1940. Despite this handicap and persistent seizures, she was able, through heroic efforts, to take care of her home for the first 7 years. Both individuals listed as hemiparetic had motor impairment prior to operation. In 3 others, not listed as having lasting postoperative weakness or spasticity of the contralateral extremities, late hemiparesis developed between 8 and 10 years after surgery with recurrence of their central and postcentral tumours.

As is well known, ligation and resection of the longitudinal sinus entails the risk of severe bilateral paralysis and death, if carried out at or behind the entry of the Rolandoic veins, unless it has already been occluded by tumour. This will be discussed in further detail in section 5 below, but it may be added
here that the occluded portion of the sinus in its central portion was resected together with recurrent meningioma thickening the falx in Patient 8 without neurological deficit.

In addition to motor and sensory cortical damage, 2 patients had difficulties with speech as a result of removing large left-sided central tumours, one extending down the entire width of the falx and bulging laterally beneath the cortex, the other arising from the falx and outcropping on the surface of the hemisphere, close to the supramarginal gyrus. The tumour removed weighed 75 gm. While hemiplegia developed in both patients in addition, the former has regained useful speech with power in his contralateral extremities (except for fine movements) and has been working as a car weigher for 15 years. The other has unfortunately been lost track of, so it is impossible to know whether his initial defects, which were present prior to operation but severe at discharge, remain or have improved. Chusid et al.\textsuperscript{2} have discussed the incidence of aphasia in cases of tumours in this area, giving descriptions of the 7 reported by Cushing and Eisenhardt and adding 2 of their own. These had their attachment to the anterior or central thirds of the falx and of the 8 survivors 2 were left with serious impairment of speech, while in 2 others recovery of speech is not mentioned. Chusid et al. have also summarized evidence from the literature that the medial surface of the dominant hemisphere may be an important accessory area in the formulation of speech.

Three individuals with large tumours in the posterior third have a residual homonymous hemianopsia, but in 2 of these the condition existed prior to surgery. Three others remained blind in one eye, as they were on admission to the hospital from severe papilloedema and optic atrophy, but with good recovery of vision in the other eye.

2. Chances of Prolonged Useful Survival. These tumours have not shown a tendency to early regrowth, as we have seen in some of our meningiomas situated under the brain in the anterior and middle fossae, where complete removal has not been possible. As shown in Table 3, the earliest recurrence was seen at the end of 2 years. This woman (Patient 22) had a pleomorphic tumour with giant cells and mitotic figures. Patient 22 had clinical evidence of a recurrence with return of seizures and left hemiparesis after 4 years, but this could not be verified, as she refused to re-enter the hospital. Only 3 others, Patients 3, 8 and 14, had later recurrences after periods of complete well-being for 10, 8 and 9 years. The average time of recurrence in these 5 cases was at 6.6 years. After reoperation Patients 3 and 8 fared less well than after the primary interventions. Patient 3, who had a 117 gm. meningioma removed from the left parieto-occipital region in 1938, was reoperated upon for a much larger tumour in 1949 and then required a third operation for a 250 gm. tumour in 1951. After this a huge hernia cerebri soon developed with sensory-motor paralysis and aphasia, with death 2 years later from multiple recurrent tumours.

Patient 8 remained well, after her first operation in 1939 for an 81 gm.
left central meningioma, for 9 years. At this time she had a return of her
seizures with hemiparesis and radiological evidence of shifting of the clips
placed along the edge of the sinus. In 1948 a large left-sided mass was re-
moved from the original site and a year later bilateral tumours together with
the falx and occluded longitudinal sinus were resected again. Despite heavy
radiation tumour recurred under the scalp which led to her death from in-
fec tion and failure of the incision to heal 8 months after a fourth operation in
1952.

Our rate of recurrence with 1 suspected and 4 verified cases among 25

<table>
<thead>
<tr>
<th>Patient</th>
<th>Location</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>Posterior third</td>
<td>R. hemiparesis, dysphasia, and return of seizures after perfect result for 10 yrs. 120 gm. recurrent tumour removed in 1949. 250 gm. recurrent tumour removed in 1951. Died 15 yrs. after primary resection of tumour.</td>
</tr>
<tr>
<td>8</td>
<td>Central third</td>
<td>Recurrence with hemiparesis, seizures, and shifting of the dural clips at side of longitudinal sinus after 8 yrs. of normal activity. 2nd resection of large central tumour in 1948. 3rd resection of bilateral tumour and thrombosed longitudinal sinus in 1949. Died 8 mos. later of necrosis of irradiated scalp and infection.</td>
</tr>
<tr>
<td>14</td>
<td>Central third</td>
<td>Return of seizures after 9 yrs. of normal life coincident with rectal carcinoma. Small central recurrence found post mortem.</td>
</tr>
<tr>
<td>22</td>
<td>Posterior third</td>
<td>Normal activity for 2 yrs. after resection of pleomorphic meningioma containing giant cells and mitotic figures. 2nd resection of large recurrent tumour 1 yr. ago with excellent result.</td>
</tr>
</tbody>
</table>

patients is greater than Dr. Cushing’s experience with 7.8 per cent in his
series of 51 parasagittal meningiomas, and Hoessly and Olivecrona’s with
only 6 per cent recurrences in their 280 cases. Simpson,19 who has made a
special study of recurrences in the 90 parasagittal meningiomas removed by
the late Sir Hugh Cairns, found an incidence of 5 per cent after complete
removals of the invaded dura mater and falx, and 17 per cent after excision
of the tumour when the falx and longitudinal sinus were electrocoagulated
but not included in the resection. The latter has been our policy to date,
except in 2 cases in which the longitudinal sinus was clearly invaded by
tumour and its resection with the attached meningioma was mandatory and
uneventful. Simpson’s statistics of Cairns’ experience demonstrate so clearly
the advantages of resecting the attached falx and sinus and that this should
be attempted whenever possible with tumours that lie in front of the inflow
of the central vein, provided the removal has gone smoothly and the patient
is in good condition with adequate exposure from carrying the bone flap well
across the midline and ensuring a slack brain. The advantages of hypothermia in this connection are discussed in section 5. Our poor results after secondary resection of recurrent tumours have impressed us with the truth of Fincher's statement that "the initial surgical effort to completely remove a meningioma is the opportunity that subsequent craniotomies do not offer."

Simpson in his discussion of recurring meningiomas has given an excellent review of its causes, dividing these into the group mentioned above that are readily explained by incomplete surgical removal and another based on the malignant tendency of the neoplasm. This is suggested by rapid growth with a tendency to invade bone and brain, undifferentiated cells with rare mitotic figures, and extremely rare instances of extracranial metastasis. There is no agreement on the relative significance in the histological appearance of a given tumour and many have developed rapid recurrence without any demonstrable changes in their microscopic appearance. Readers who are interested in this subject should refer to Simpson's article and his thorough review of the literature. In this series only a single case was encountered in which the cells showed a tendency to pleomorphism and the tumour recurred after a brief interval of 2 years. In our 4 other recurrences histological examination by Dr. E. P. Richardson showed no change in the character of the tumour cells, even after the increasing rapidity of recurrence and clinically malignant course in the 2 patients who, after symptomatic recovery for 8 and 10 years, again had recurrences within 1 to 2 years after secondary operations. One of these died after the fourth operation and in the other multiple recurrent tumours developed after a third operation that caused his demise 2 years later.

The diagnosis of a recurrent meningioma is often difficult. In our 5 cases evidence that pointed in this direction and led to more careful testing consisted of a return of epileptic seizures after prolonged freedom in 4, with recurrence of hemiparesis in 3 of these and added aphasia in 1. In addition, roentgenograms in 1 of these patients showed a distinct shift in the dural clips applied to the side of the longitudinal sinus. In the fifth patient with recurrent meningioma a palpable tumour nodule developed in an area where the bone flap had been resorbed.

Table 4 shows that of the 24 who survived their primary operations, 10 were able to return to active work without noticeable handicaps, one as a practising surgeon. Five of these, however, Patients 2, 3, 8, 14, and 22, suffered recurrences 4, 10, 8, 9, and 2 years later. Eight of the others were able to carry on with their household duties or remunerative work, although with variable degrees of handicap. Patent 17 was unable to return to work because of a pre-existent psychosis that necessitated her living in an institution. Patient 19, with a severe right hemiparesis and aphasia at discharge, has been lost track of, but it is most unlikely that he has made a useful recovery. One other individual, Patient 9, was too incapacitated from her left hemiplegia to return to an active and useful life, although she managed to
do some of her housework for 7 years. Three others have been operated upon during the last 20 months. All appear to have recovered well, but it is too early to evaluate the final effectiveness of surgery.

3. Tendency to Seizures. As brought out in Table 5, the high incidence of epileptic attacks is the most outstanding manifestation of meningiomas that develop along the longitudinal sinus and falx. Cushing and Eisenhardt have likewise commented on the high proportion of seizures with meningiomas in this region. While meningiomas in general that have been operated upon at the Massachusetts General Hospital have a complicating incidence of seizures in only 35 per cent (White et al.)* 84 per cent of this series have suffered from convulsive episodes as a primary or later complaint. This
tendency to seizures increases as the attachment of the tumour approaches the central strip, the incidence being 92 per cent in individuals with central meningiomas and 50 per cent with lesions attached either to the posterior or the anterior thirds of the falx. A somewhat similar topographic relationship to frequency of fits is seen in cases of gunshot wounds of the head that pene-

---

* This is far less than the seizure incidence with meningiomas reported by Penfield and Erickson of 67 per cent, but we feel that statistics from the Neurological Institute in Montreal must be heavily weighted from the fact that so many sufferers from epilepsy seek Dr. Penfield’s advice.
trate the dura mater, in which Ascroft has reported that "lesions near the sensori-motor cortex more often lead to epilepsy than do those at the poles of the cerebral hemisphere."

The convulsive manifestations observed with these parasagittal tumours corresponded closely to the characteristic patterns described by Penfield and Kristiansen. To summarize these briefly, 3 out of 4 patients with frontal tumours and epileptic attacks had immediate blackouts without any aura; 1 had loss of speech with incontinence of urine. Adverse turning of the head and eyes was not observed. Of the 12 individuals with central tumours attached to the longitudinal sinus, the 11 who complained of seizures suffered from attacks characterized by sensory or motor activity in the leg or arm. In 3 of them, contrary to expectations, the arm alone was involved. It is of interest to note that there were distinct complaints of pain in the contralateral shoulder or torso in 3 of this group, which were presumably of central origin, as in 1 complete infiltration of the brachial plexus failed to modify the discomfort in any way. This phenomenon has previously been described by Michelsen, Penfield and Kristiansen, and White and Sweet. It seems definitely related to meningiomas growing in the region of the postcentral sensory strip. The 2 individuals with meningiomas attached to the posterior third of the longitudinal sinus who complained of seizures had sensory aurae in the wrist and leg with additional transitory difficulty with speech in the one with the tumour on the dominant side. Finally, in the 2 patients with meningiomas growing from the deeper portion of the falx without attachment to the longitudinal sinus, the seizures in one corresponded with the site of the tumour which lay in contact with the foot area on the medial surface of the hemisphere. In the other, in whom the tumour was in contact with both the foot and the arm area because of a lateral outcropping in the postcentral cortex, the sensory-motor seizures involved both extremities on the opposite side. He also complained of pain in the shoulder at the time of his attacks.

After surgical removal of 16 epileptogenic meningiomas in patients we have been able to follow from 1 up to 18 years, seizures ceased in 9, and became less severe, more infrequent, and more easily controlled by anticonvulsant medication in most of the others. An occasional seizure after operation does not indicate a poor prognosis, as a number of these patients required continuance of Dilantin up to a year before the attacks stopped and anticonvulsant medication was no longer necessary. Postoperative seizures, when present, were so well controlled by anticonvulsant drugs that all of the patients were able to work; but they could no longer be controlled by medication when the tumours recurred. Attacks returned in Patient 8, and again became incapacitating in Patient 3 after periods of 8 and 10 years with recurrence of the central and posterior tumours. Patient 14 also suffered a return of seizures after 9 years without other evidence of regrowth of her central tumour. This woman was then readmitted with advanced rectal
PARASAGITTAL MENINGIOMAS OF SINUS AND FALX 205
carcinoma and found to have a 3 cm. recurrent nodule at autopsy. This is a
somewhat better record than that of Cushing and Eisenhardt,3 who reported
on page 449 that "the continuance of epilepsy after removing tumors of the
middle third has been highly disconcerting" and added that the cessation of
irritative seizures was encouraging only in cases of small tumours after
prompt intervention. This of course was before the discovery of Dilantin and
other effective anticonvulsant drugs. In counting up their tabulated statist-
cs we find that, of 28 patients complaining of seizures before operation, 21
continued to suffer convulsive attacks after the parasagittal tumours were
removed. The return of convulsive attacks after a prolonged period of
freedom appears to constitute definite evidence that the tumour is recurring.

4. Electroencephalographic Findings Before and After Surgery. In only
11 of the 25 patients of this series were we able to determine with certainty
the existence of preoperative electroencephalograms. In 15 of the 25 a
number of postoperative electroencephalograms were obtained and a total
of 59 are available for study. Three patients who had preoperative electro-
cephalograms did not have postoperative recordings. The total number of
patients that had electroencephalograms is 18.

For a long time it has been noted by electroencephalographers that the
parasagittal meningiomas as a group are more difficult to localize precisely,
for reasons that have never been very clear. This may possibly be attrib-
utable to the fact that a tumour in this area of the hemisphere affects by
direct pressure a considerable portion of the hemisphere opposite. In the
early days of electroencephalography midline electrodes or electrodes close
to the midline were not used routinely, which may account for some of the
negative electroencephalograms reported on patients with definite evidence
of tumour. In the past 10 years, however, these leads have been used routine-
ly in all laboratories and the number of inconsistent electroencephalograms
has been reduced gradually. The small number of completely normal
electroencephalograms following total removal of a tumour of this type is
consistent with the fact that the patient frequently continues to have
seizures for some years after successful removal, indicating that the scar
formation after resection is a permanent or long-occurring source of elec-
trical irritation. For this communication we have gone over every tracing
again, and in only one record was it necessary to alter significantly the inter-
pretation of the record. Actually in this group of 15 patients the abnormal
electroencephalographic findings correctly localized before operation were
7 of 11, 3 being normal and 1 diffuse; the postoperative electroencephalo-
graphic findings were: normal 3, abnormal 12.

In Fig. 1, in the upper part, there is listed the number of abnormal
tracings in the two groups. In the second part of Fig. 1, there is a diagram-
matic arrangement of the total number of patients according to the amount
of abnormality on a vertical scale, the bottom of the scale being normal. The
vertical line indicates the time of operation. Note that 3 patients had normal
brain waves prior to operation. One continued to be normal, the other 2 became abnormal. Eight patients started with abnormal records. The circle marked X represents 2 patients whose records were abnormal to begin with and after removal of the tumour gradually became normal. In 2 patients after operation a worsening of the electroencephalogram slowly developed and this led, when correlated with other findings, to re-exploration, whereupon recurrence of the tumour was encountered. Three other patients with recurrences that were operated on did not show this worsening of the elec-

<table>
<thead>
<tr>
<th>PREOPERATIVE E.E.G's</th>
<th>POSTOPERATIVE E.E.G's</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal</td>
<td>Abnormal</td>
</tr>
<tr>
<td>3</td>
<td>8</td>
</tr>
</tbody>
</table>

![Diagram](image.png)

Fig. 1. Top: Number of preoperative and postoperative electroencephalograms. Bottom: Diagrammatic plot of change in electroencephalogram after removal of meningioma. Vertical line representing degree of abnormality is set at time of surgery. X represents 2 patients whose records became completely normal after operation. One of these had an abnormal tracing before surgery, the other had no preoperative tracing. The 2 worsening electroencephalograms were in patients who had recurrence of tumour. Three others with recurrent tumours did not show this. The general postoperative pattern is a slow improvement over years without return to normal.

troencephalogram, but it remained abnormal, and did not improve during the postoperative period. These recurrent tumours could not be completely removed and soon started to grow again.

The general pattern in this group of patients was for the abnormality to persist for some time after removal of the tumour; frequently it was worse and more focalized than in the preoperative tracing. However, over the passage of time, usually from 2 to 5 years, the records became less abnormal in 8. Fig. 2 shows an example of this type of electroencephalographic finding. This patient had 6 serial postoperative electroencephalograms as well as 1 preoperative. The preoperative one was normal and 5 of the postoperative ones were abnormal, but the abnormality gradually disappeared. The focus
where the tumour was removed persisted for 3 years and then there was a gradual improvement, so that the final electroencephalogram that is shown in the right lower tracing of Fig. 2 is nearly normal. Actually, it is the exception for the record to become completely normal. Along with this gradual betterment of the electroencephalogram there was usually a disappearance of the epileptic seizures, as well as clinical improvement. It may be concluded from this small electroencephalographic serial study that two-thirds of the operative meningioma records were correctly localized and remained abnormal postoperatively, even though the tumour had been removed successfully. The records tend to remain focally abnormal and then gradually improve, if recurrence of the tumour does not develop. The presence of a worsening record is strongly suggestive of recurrence, and a gradually improving record is against recurrence. It is important in following any patient in the
It is obvious from this study that the value of electroencephalography would have been increased if each patient had had a preoperative electroencephalogram, or preferably two, one being done shortly before surgery; and if each postoperative patient who survived had had at least five serial electroencephalograms, one in the immediate postoperative period, and the others at subsequent years throughout the follow-up period. If this had been done the total number of records would have been approximately 160 to 200. This would have been an ideal number for study instead of the inadequate 59 records that are reported in this communication.

5. Plans for Further Improvement of Surgical Technique. We have already emphasized the special hazard of injuring vital cortical areas in dealing with meningiomas attached to the central portion of the longitudinal sinus or underlying falx. All of our 7 cases of postoperative motor-sensory defects and aphasia occurred in this group, though whether the injury resulted primarily from cortical trauma or the necessity for clipping and dividing the vein of Rolando draining the central sulcus is difficult to ascertain. Its interruption is likely to result in a weak, spastic leg, if not with some involvement of the arm. The 2 instances of complicating aphasia both occurred in patients with meningiomas which extended far laterally into the hemisphere. One of these, in whom there was outcropping of tumour in the region of the supramarginal gyrus, had definite dysphasia prior to operation. Even more serious bilateral complications are likely to arise if the longitudinal sinus is ligated posterior to the inflow of the central veins, unless it has already been thrombosed by tumour. This constitutes a particular hazard if the unoccluded sinus is ligated at the site of entry of the Rolandic veins, as sudden bilateral occlusion of venous drainage from the central sulci seems to be incompatible with survival. Jaeger has reported 2 such fatalities, although a third patient survived with only a residual unilateral visual field defect when the unoccluded longitudinal sinus behind the central area was resected. The experience of others in this connection and a review of the literature is reported in articles by Maltby and Merwarth. Since Simpson has shown so conclusively that the incidence of tumour recurrence is reduced threefold when the invaded portions of the longitudinal sinus and falx have been resected, it is advisable to remove this area whenever possible. As external inspection and palpation of the sinus may be misleading, Jaeger has made the logical suggestion that its occlusion at or posterior to the inflow of the central veins should be determined unequivocally by venography or passage of a fine probe through an opening in the sinus made in front of the tumour at the time of operation.

In this series the central portion of the longitudinal sinus has been resected on only one occasion on which it was found occluded by tumour and
its removal led to no ill effect. Nevertheless there are cases on record (Hoessly and Olivecrona) in which resection of even an occluded portion of the posterior two-thirds of the sinus has led to serious paralysis or swelling of the brain from added damage to collateral venous circulation. Perhaps in a situation of this sort it may be possible to insert a venograft to prevent dangerous back pressure on the vital central veins. To reduce complications we intend henceforth to explore the advantages of hypothermia in operating on meningiomas that arise from the central portion of the longitudinal sinus, where bridging veins enter which drain the motor area and may have to be sacrificed. Experimental evidence cited by Rosomoff has demonstrated that even ligation of the middle cerebral artery can be tolerated in animals under hypothermia maintained an hour before rewarming is started. This relatively brief period appears to be sufficient to permit the establishment of a competent collateral. While this has not prevented the development of hemiplegia in some of our cases of arterial injury, it should be more effective with the venous circulation, and it is always possible to delay the period of rewarming if the patient shows any evidence of weakness during his recovery.

In addition to the advantage of the lowered cerebral metabolism and concomitant ability of cortical cells to withstand partial ischaemia for prolonged periods while collateral circulation develops, there is a tremendous advantage in operating on a shrunken brain. Here again Rosomoff has demonstrated in dogs that the brain at 25°C decreases 4.1 per cent in volume and that the free space between the brain and skull is increased as much as 30 per cent. With a 1500 gm. brain this should represent an increase of 60 cc. in the space between brain and skull. This experimental finding has been corroborated by Lundberg and Nielsen’s observations on the fall in intraventricular pressure on cooling human patients and by many observations in the course of operations on the human brain under hypothermia (Sedzimir and Dundee). Any manoeuvre that permits more gentle retraction to gain space between the falx and a tense hemisphere is of incalculable advantage to the surgeon in removing a deep tumour and sparing the bridging veins or in gaining space to resect the invaded falx and longitudinal sinus. This is well brought out in the following case history of a patient with a dumbbell-shaped tumour extending into the deep central portion of each hemisphere from the inferior central portion of the falx.

A 17-year-old boy complained of Jacksonian seizures starting in his right foot. At the time when the attacks spread to his right arm he would lose consciousness and have a generalized seizure. His neurological findings except in the postictal stage were not remarkable, but the electroencephalogram and positron scan showed an abnormal focus in the central region. He was left-handed. Although an arteriogram demonstrated only minor abnormalities of the pericallosal arteries, a ventriculogram showed the mid-portions of both lateral ventricles to be depressed, more so on the left than on the right.

At the first left-sided craniotomy, carried out on Aug. 30, 1957 by Dr. Vernon
Mark, it was necessary to sacrifice the Rolandic vein in order to retract the hemisphere and to expose the deep-seated dumbbell tumour, which projected 3 cm. from a 2.5 cm. attachment to the lower half of the falx. Because of the swollen, tense brain it was impossible to accomplish more than an exposure and biopsy of the tumour, and the bone flap had to be left out in order to close the incision.

Following this frustrating procedure a severe hemiplegia developed. Fortunately there was no accompanying aphasia, and within a month the hemiplegia had cleared except for a mild residual weakness in his right foot.

At the second operation under hypothermia (carried down to ~9~ his cerebrospinal fluid pressure fell from 110 to 70 mm. At this operation, carried out by Dr. Mark and one of us (J.C.W.), the left-sided incision was reopened and the brain was found so slack that it proved an easy matter to expose the tumour on the left and remove it piecemeal. The falx, surrounding the area invaded by tumour, was then easily resected, so that the longitudinal sinus was left intact above and a 2 cm. projection of the dumbbell meningioma was lifted out from the right side.

Convalescence from this procedure was uneventful. The patient has since had the bone flap replaced, and the residual weakness of his leg has cleared. Seizures have continued since operation, but their incidence is decreasing. The electroencephalographic tracing 4 months after total resection of the tumour is much improved over the preoperative tracing, and the arsenic scan no longer shows an abnormal uptake of the positron-emitting isotope.

**SUMMARY**

Removal of parasagittal meningiomas should give the best surgical results of any type of intracranial tumours. This report covers the detailed preoperative studies and postoperative follow-up in a consecutive series of 25 patients operated upon by the senior author in the past 20 years. It includes the electroencephalographic findings in the 18 patients whose tracings are available, and their significance in connection with seizures and recurrence of tumour is emphasized.

The points of special interest are:

1. The low postoperative mortality (8 per cent per case and 4.3 per cent per operation) and relatively low morbidity, the result of modern operative and anaesthetic techniques.

2. The probability of prolonged useful survival: Of the 21 patients followed for over a year, 10 have been able to resume their former work without serious difficulty from 1 to 20 years, and 8 others to lead useful lives with surmountable handicaps. One is prevented from working by a serious pre-existent psychosis. Only 2 remained incapacitated because of residual hemiplegia. Five have suffered recurrences after freedom from symptoms for periods ranging between 2 and 10 years.

3. The predominant tendency for meningeal tumours in this region to produce epileptic seizures as part of their symptomatology and the increasing incidence of spells the nearer the tumour lies to the central sulcus: Eighty-four per cent of these patients entered the hospital with a history of seizures. In the 16 whom we have been able to follow for prolonged periods
after operation, seizures have ceased in 9 on anticonvulsant medication and they have ultimately been able to discard Dilantin. Seven others have continued to have attacks despite medication, but these have usually been mild and infrequent. In 4 of the 5 patients with recurrences seizures eventually returned.

4. Electroencephalographic findings showed the following:
   (A) Preoperative: Out of 11 patients with seizures the electroencephalographic tracings were normal at first in 3, 2 of which later became abnormal. The electroencephalograms in the other 8 were abnormal and the focus was correctly localized in 7 of these.

   (B) Postoperative: Two postoperative abnormal records reverted to normal and 1 patient who had normal postoperative records had no preoperative test. In 12 other patients tested postoperatively abnormal tracings in the area from which the meningioma had been resected persisted in all. Eight of these postoperative records showed an improvement in the electroencephalogram, in spite of some abnormality in the record. The greatest improvement occurred in those whose seizures had disappeared and who required no anticonvulsant medication. Postoperative electroencephalograms in 4 patients remained abnormal, those in the 2 with recurrences becoming increasingly worse.

   (C) The electroencephalographic pattern does not help in distinguishing between meningioma and other types of parasagittal tumour, nor between residual cortical gliosis and recurrence of tumour.

   Plans for future improvement in surgical technique and the advantages of operating under hypothermia are discussed.

REFERENCES


