Acoustic tumors have been observed at autopsy at least since the eighteenth century, and isolated clinical accounts of this condition began to appear during the first half of the nineteenth century. During the second half of the nineteenth century, the clinical diagnosis of acoustic tumors was perfected as more cases were reported and as the mechanisms of cerebellar function were elucidated by experimental studies. Ancillary techniques were soon developed to further perfect the diagnosis of these tumors.

"In 1912 the young Swedish pathologist, Folke Henschen, soon to become Professor and now one of the world's leading neuropathologists, added an important contribution. He was already well known as an authority on acoustic tumors. In his communication Henschen gave an excellent up-to-date account of the value and limitations of radiology in the diagnosis of brain tumors and went on to describe how he had found at autopsy that acoustic neuromas nearly always widened the internal auditory meatus. He felt convinced that this feature should be demonstrable radiographically in life and he sought the aid of his radiological colleague Dr. Forssell."

"In February, 1910, Henschen had a case of suspected acoustic tumour which he submitted to radiography. Unfortunately only one side of the head was X-rayed and the patient was allowed to depart. Henschen had to wait just over a year for another case (March, 1911). On this occasion he obtained two radiographs, one of the normal and the other of the abnormal meatus. The patient died in April and Henschen confirmed the radiographic findings at autopsy."

By later modifications in radiological technique, Stenvers and Towne each increased the usefulness of Henschen's original observation.

Another significant contribution to the diagnosis of acoustic tumors was made by Robert Bárány when he originated the caloric tests of vestibular function. Bárány had been born in Vienna in 1876, and after his formal medical training, he returned to that city to practice. He restricted his work to otology and soon became widely recognized for his studies of vestibular function.

"... In 1913–1914 he was awarded a number of international prizes, culminating in his selection as Nobel laureate. The confusion which accompanied the outbreak of the First World War caused postponement of the 1914 award until 1915. At that time Bárány was a Russian prisoner of war in Siberia. Through the intercession of the Swedish Red Cross, however, he was released, and the award presented to him through diplomatic channels."

The operative treatment of acoustic tumors began during the last decade of the nineteenth century.

"... However, in most cases, the results were poor. ... At the International Congress of Medicine in 1918 in London, von Eiselsberg reported 16 cases with 15 immediate fatalities, Krause reported 31 cases with 26 deaths. Thus, the over all operative mortality in this condition was almost 80 per cent. These poor results were attributed by Cushing to excessive emphasis on speed of execution and attempts to remove the tumor completely by finger enucleation. As was his custom, he proceeded in a much more painstaking manner, with the result that he was able to lower the operative mortality to 15 per cent by 1917."

"Feeling that none of the originally used procedures provided enough room, and that the cerebellum and brain stem were traumatized by efforts to work in a restricted field, Cushing utilized the cross-bow incision, and recommended that the entire operation, wherever possible, be carried out in one stage. After performing a bilateral craniectomy, and tapping the lateral ventricle, the dura was opened in stellate fashion, the cerebellar hemisphere retracted medially and the tumor exposed. Cushing felt that attempts at total extirpation had led to the high mortality rate, and therefore suggested merely incising the capsule of the tumor and enucleating the tumor piecemeal from within, leaving the capsule in situ."

"In November, 1920 Cushing, in remarks at a meeting held at the Peter Bent Brigham Hospital, reported final statistics in 47 cases of acoustic nerve tumors with end results and pointed out that among the last 19 consecutive patients operated upon by him there was only one surgical death, bringing his operative mortality for this most difficult surgery down to 5.3 per cent!"
“By a curious coincidence, in the very year (1917) that Cushing published his classic monograph ‘Tumors of the Nervus Acousticus,’ in which he made the following statement: ‘I doubt very much, unless some more perfected method is devised, whether one of these tumors can safely be totally enucleated,’ Dandy[10] presented before a local meeting of the Johns Hopkins Medical Society a patient from whom he had successfully extirpated in toto a tumor of the nervus acusticus while his surgical chief, Dr. Heuer, was out of town. This trick of fate seemed to fire Dandy with a special zeal to out-do Cushing in the latter’s own special domain . . . .

“In 1932 Dandy[10] reported two more successful total removals of acoustic nerve tumors, and in 1935[11] he reported 17 cases in which the tumor had been totally removed, but with 7 deaths; however, in 12 of these cases the tumor had been shelled out with the finger and all of the 7 deaths occurred in this group; in the 5 cases in which the capsule had been carefully dissected away from the pons there were no deaths. In 1934 Dandy[12] described an operation for the removal of acoustic nerve tumors through a unilateral approach, but did not give any statistical results for this modification . . . .”[14]

Seven years later, Dandy[13] supplied these results. There had been only 5 deaths in his series of 46 cases, a mortality of 10.9 per cent.

“The great disadvantage of the total excision method of treating acoustic tumors was the facial distortion resulting from the damage to the seventh nerve. Although surgeons had considered attempting to spare this nerve, it was not until 1931 that this was achieved. Cairns[5] in the course of removal of an acoustic tumor recognized the nerve and was able to complete the excision without sectioning or destroying it. Olivecrona[22] after 1937 attempted to save the nerve in every case. In 1940 he reported on 25 cases with anatomical preservation of the nerve in 15 cases. In 14 of the latter facial paralysis developed, but function returned in a few months to a year in almost all cases . . . .”[17]

The experience of other neurosurgeons with the techniques of Cushing and Dandy showed that the morbidity and mortality associated with the total removal of acoustic nerve tumors was consistently greater than the morbidity and mortality accompanying their partial, intracapsular removal.[16, 19, 21, 37]

“. . . Survival after operation, however, is not the only consideration in evaluating the operative results. As reported by Cairns,[6] among 10 patients who had had intracapsular removal of the tumor by Cushing while Cairns was associated with Cushing, there were 8 survivors after an interval of 9 years, but only 3 were able to work, 2 had considerable disturbance of gait, and 3 were severely incapacitated. Givré and Olivecrona (1949) further pointed out that 50 per cent of their patients who had had the intracapsular operations had either died or had been reoperated upon within 3 to 4 years with a 50 per cent mortality attending the second operation.”[24]

These experiences, combined with the development of techniques for restoring the function of the facial nerve, have resulted in the present emphasis on the total removal of acoustic tumors.[20, 24]

References


AN OPERATION FOR THE TOTAL REMOVAL OF CEREBELLOPONTILE (ACOUSTIC) TUMORS*

BY WALTER E. DANDY, M.D., BALTIMORE
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Potentially benign lesions, usually easy of recognition, not difficult of operative approach or even of enucleation, nevertheless tumors of the cerebellopontile angle have presented surgical problems which have seemed well-nigh insuperable. Surely few lesions have enticed surgeons with more alluring prospects and have ultimately yielded so little reward for their best efforts for, with few chance exceptions, patients have succumbed following total or attempted total extirpation of the tumor. At the beginning of the twentieth century it seems probable that there had been but one tumor of this kind completely and successfully extirpated—one removed by Ballance (2) in 1894 and reported in 1907. Although there is some uncertainty as to the exact nature of this tumor (he terms it a fibrosarcoma), it seems highly probable that it was really one of the true cerebellopontile variety. It was clearly an encapsulated tumor in this region, yielding out readily with the finger, and the patient’s survival for many years is alone sufficient evidence to preclude a sarcoma. Moreover, as most of these tumors in earlier years have been recorded as gliosarcomata—a classification well justified by the histological picture—such an entry is evidence in favor of the tumor being of the cerebellopontile variety.

At the beginning of the twentieth century cerebellopontile tumors were recognized by their more or less characteristic signs and symptoms and became a fairly well established clinical entity. Oppenheim of Berlin, Sternberg of Vienna, v. Monakow of Zurich, Hughlings Jackson and Gowers of London, Babinski of Paris, and Allan Starr of New York, were not only pioneers in the recognition of these tumors but they stimulated a group of surgeons to undertake their removal.

At the International Congress of Medicine in London in 1913, the three great European surgeons—Horsley of London, v. Eiselsberg of Vienna, and Krause of Berlin—who had in such large measure been responsible for the birth and

* Reprinted from Surgery, Gynecology and Obstetrics, 1925, 41: 129–148, with the kind permission of the Editor.

1 This group of tumors has long been recognized as a distinct clinical and pathological entity. Various other tumors in this region, whether encapsulated or infiltrating, have not been considered. I prefer the designation "tumors of the cerebellopontile angle"—the Kleinhirnbrueckenwinkeltumoren of the Germans—rather than "tumors of the acoustic nerve" for this well known group of encapsulated tumors because it does not include a theory of origin. Both appellations are defective—"cerebellopontile angle" because it merely denotes a location which is the abode of other tumors of varying types; and "acoustic" because the origin of the tumor is still in dispute and also because there are other tumors of the acoustic nerve which, both in structure and position, are entirely unlike those under consideration. Throughout the remainder of the paper the abbreviated term "cerebellopontile tumor" will be used. Though even less accurate, it has attained significance through general usage and has obviated the tendency to use the clumsy and grammatically incorrect expression, cerebellopontile "angle" tumor.
growth of brain surgery, presented their results on the extirpation of cerebellopontile tumors to that date. Horsley had 10 operative deaths in 15 cases (67 per cent), v. Eiselsberg 13 deaths in 17 cases (77 per cent), and Krause 26 deaths in 31 cases (84 per cent). Krause admitted they yielded the poorest results of all his brain tumors. There seems to have been no very great difference in the methods of attacking the tumor. Each used a unilateral cerebellar approach, often little more than an enlarged trephine opening, and the tumor was quickly shelled out with the index finger or spatula. Because of the disastrous results, the operation was often performed in two stages, particularly by v. Eiselsberg and Horsley. Sometimes Krause used suction to draw the tumor from its bed.

The conference ended with no prospect of better operative results in the future. In the hasty and necessarily blind extirpation of these tumors through a totally inadequate exposure, many of these tumors were broken and only partially removed, necropsy revealing more or less tumor undisturbed. Moreover, those few patients who survived were almost without exception badly crippled. So far as I am aware, the ultimate results of the few successes of Horsley, Krause, and v. Eiselsberg were never published, but a fortunately timed publication of Tooth (18) at the same International Congress in London, 1913, presents a comprehensive statistical study of the operative results in all brain tumors from the National Hospital of London to the date of this conference (1913), and appended thereto is a brief summary of each case together with the operator, operation, and, so far as known, the ultimate results. If not including all of Horsley's work, this report at least gives us a fair insight into his results. From this dismal story we learn much concerning the fortitude of these great pioneer brain surgeons who nevertheless persevered to blaze a trail through a forest which must have seemed utterly impenetrable. Looking back, it is clear that they were ill equipped for such a struggle; until the latter part of their work surgery was yet in its infancy. Cranial surgery offered technical problems foreign to those of other tissues; instruments of special character had to be devised; the control of hemorrhage from bone, the brain, and tumors, was unlike that elsewhere. A knowledge of the functions of the various parts of the brain and of the cerebrospinal fluid was only slowly accumulating. The effects on intracranial pressure of the immediate injury to cerebral tissues were at best imperfectly understood; and the avoidance of trauma continued to be almost impossible because technical difficulties prevented sufficient exposure of the desired field. Moreover, sepsis continued to exact a not inconsiderable toll. Though Horsley, v. Eiselsberg, and Krause were all firm adherents of the Listarian principles of combating infection, the avoidance of infection had not been mastered. And, last but not least, neurology was also just developing so that the diagnosis of tumors was usually made when the patient was blind and often in extremis. Cerebellopontile tumors, however, had one great advantage over all other brain tumors: not only could fair diagnosis and localization be made with fair accuracy, greater as time passed, but the tumor was known beforehand to be benign and encapsulated. The surgical problem, therefore, was direct.

With a minimum of scientific equipment, the struggle for solution of this surgical problem was necessarily in large part through trial and error, but the great Horsley early added to neurological surgery the far-reaching and invaluable method of animal experimentation, but shortly before begun by Fritsch and Hitzig in Germany and by Ferrier in England.

One hardly knows whether to admire the indomitable courage of the surgeon or the persisting faith and hope of the neurologist the more. The story contained in these struggles differs only in degree from that of the pioneer efforts in advancing the frontiers of knowledge. It is, therefore, without possible taint of a critical attitude that the statistics of Sir Victor Horsley are studied. Without his contributions, both technical and physiological, to this field of surgery—his bone wax, his method of controlling hemorrhage with pieces of excised muscle, and his introduction of decompressions in order to combat acute postoperative intracranial pressure, etc.—it would not yet be possible to cope with the many problems of intracranial surgery.

Returning to Tooth's analysis of operations for tumor, we find under the heading "Extracerebellar Tumours—Removal of tumour, complete or partial," 12 cases of cerebellopontile tumor operated upon by Horsley. From this group of cases, 5 (42 per cent) survived the operation for periods of 6 weeks, 21 months, 3 years, 3 years+ and 8 years.

2 In grouping these cases as cerebellopontile tumors, I have taken the liberty of disregarding Tooth's historical classification of tumors (glioma, fibroglioma and fibroma) and including those tumors which, from the history of the patient (early deafness with other symptoms appearing late) and even more the gross appearance of an encapsulated enucleable tumor in the angle, appeared to me probable tumors of this variety. For example, Case 222, entered as a glioma by Tooth, impressed me more as being a cerebellopontile tumor, and two cases of bilateral tumor classified by Tooth as fibroglioma, I have excluded, feeling that they were probably rather examples of Recklinghausen's tumors. I have also included four of Horsley's cases grouped under fibromata. As Horsley refers to fifteen cases at the same meeting, it is fair to assume that he and Tooth (who includes fourteen) refer to the same cases.
+; of these, 3 died of recurrence at the times stated, 1 had signs of recurrence at the end of 3 years (the wound was bulging and tight) and the last case was well and active 8 years after the operation. Of the 7 deaths (58 per cent), 2 were from meningitis on the sixth and seventeenth days. It is evident that Horsley has included in his own mortality statistics two deaths which occurred at 6 and 10 weeks, and included in his living cases one which lived 11 months after removal of a tumor on one side and died following extirpation of a second growth in the other angle, a case almost surely of Recklinghausen's disease and not of cerebellopontile tumor. But the most important result in Horsley's series is not his mortality rate but the report of the necropsy findings. Of six necropsies, in only one case had the tumor been totally extirpated, the remaining five showing more or less tumor still undisturbed. In two cases the cerebellar lobe had been very badly damaged.

Tooth's remarks on the results following extirpation of these tumors (including 5 cases operated upon by other surgeons at the National Hospital without a single recovery), well express the situation and faint degree of hope at that time. "The diagnosis of tumours in this region is so comparatively easy and accurate, and the surgical treatment at first sight so straightforward, that the results in this table are disappointing in the extreme. ... No doubt the proximity to the vital centres is accountable for great shock, with respiratory and cardiac failure. If the danger of that period can, by any alteration in surgical procedure, be eliminated, there is no reason evident why these cases should not do well."

Nor had this impression of the surgical treatment of cerebellopontile tumors changed in England during the following 10 years, if we may judge correctly from the following quotation from Gordon Holmes (11), when discussing a case presented by Walshe (20) before the Royal Society of Medicine: "It was perhaps presumptuous on his part to refer to the surgical treatment, but so many of his cases had passed through the hands of surgeons that he had had some experience in the matter. He had seen one case recover only after gross removal of the tumour, a man upon whom Sir Victor Horsley operated many years ago, but though he lived for several years he was seriously crippled. The danger seemed to be that total removal necessarily meant a disturbance of the vascular supply on the same side of the pons and medulla; the man to whom he referred had, after the operation, the characteristic symptoms of softening in the lateral side of the pons. He saw a few other cases which had survived operation for a week or so after total removal of the tumour, and all showed evidence of acute bulbar involvement."

The aggregate number of total extirpations of these tumors with recovery to date and freedom from recurrence, is impossible to estimate but with liberal allowance it will probably be less than half a dozen—and we are positive of only two. Foremost of these cases is the one removed by Ballance (2) in 1894. Apparently the only permanent sequelae of the operation many years later were palsies of the fifth and seventh nerves; the former had resulted in corneal ulceration and loss of vision in that eye. The second undoubted cured case is that of Horsley, From Eiselsberg's series (9) of four recoveries (including one by his assistant, Clairmont) from the operation, one was able to resume work on the farm but there is no other record noting the ultimate results and freedom from recurrence. Leischner (13) collected from the literature eleven cases which had survived operation. Among these were four from Eiselsberg's Clinic, one of Horsley's (this was before Horsley's report (1913) of five recoveries), Krause (12) one, Poppert (16) one, Baisch (1) one, and Borchardt (2) three. This ensemble, however, is of little significance; they should not be confused with cures, for aside from the cases of Ballance and Horsley, and possibly one of Eiselsberg's, the subsequent evidence of their cure has not appeared. In the light of the necropsy reports in Horsley's cases, in which but 1 of 6 cases was shown to be totally removed, it would appear fair to presume that few if any of these had been totally extirpated and the patients permanently cured. One of the best results reported in this group of tumors was by Willy Meyer of New York (14, 1912). In two stages, 4 weeks apart, this tumor was removed with a spoon. Three years later he was apparently well, but we have been unable to find subsequent notes on this patient's condition.

The operative method used by all operators was essentially the method of Horsley, v. Eiselsberg and Krause. A two-stage procedure came to be used almost universally and usually the dura was not opened in the first step. It seems probable, however, from Tooth's reports that Horsley always opened the dura and, toward the last at least, his decompression was bilateral. The unilateral exposure of the affected side of the cerebellum was used by Krause and v. Eiselsberg. Krause (12), it is true, suggested a bilateral cerebellar approach, but it was designed for exploration of the posterior fossa and was not intended to be used when the tumor was known to be in the cerebellopontile angle. It appears that in many instances the opening in the occipital bone was but little larger than necessary to insert the finger or spatula. The tumor was removed by sweeping the finger or spatula around the tumor and mak-

2 Doubtless this reference is to the same patient whom Tooth (1913) mentioned as living and well (with V and VII paralysis) 8 years after operation.
ing the traction necessary to dislodge it. The finger was preferable for it could better detect the cleavage plane between tumor and brain stem. After such extirpations, furious bleeding must have been inevitable. Always the lobe of the cerebellum was injured, often much of it destroyed, and at times even deliberately removed. Not infrequently the tumor was extirpated through a transcerebellar defect which reached the upper surface of the tumor. Frazier (10, 1905) indeed urged deliberate resection of the outer part of the cerebellar hemisphere and, though a heroic procedure, it probably caused no greater damage to the lobe than that which customarily resulted from these extirpations.

Krause (12, 1903) introduced a very useful procedure to reduce the excessive pressure which was nearly always present with cerebellopontile tumors. A trocar was passed through the tentorium into the lateral ventricle permitting the evacuation of its fluid. This procedure (ventricular puncture), in much more refined form, has come to be a most important item in all operations for tumors below the tentorium.

Perhaps the translabyrinthine approach suggested by the otologist Panse (15, 1904) should be mentioned in passing. At the time this method was proposed, attempts to remove cerebellopontile tumors appeared utterly futile and any suggestion might at least be tolerated. But it was a wholly impractical suggestion. After destroying much of the petrous bone, including the labyrinth and much of the mastoid bone and its contained air cells, and after passing through fields which could not be sterilized and might well harbor dormant infections, the resulting exposure must necessarily have been so meager that it would hardly be possible to do more than nibble at these great tumors. Quix (17, 1911) hastily reported the removal of a pea-sized tumor by this method but the patient died a few months later. The usual large recess tumor was present; its surface had only been scratched! The one prerequisite of any operative approach is adequate room to afford thorough inspection of the tumor during its attack in order to permit the deliberate control of hemorrhage. This exposure being lacking in the translabyrinthine approach, other consideration of the procedure is useless.

Inevitably a severe reaction must appear against attempts to remove cerebellopontile tumors, particularly as the gamut of possibilities, both of method and of individual skill, had apparently been run. All of the accumulated technical advances of a quarter of a century had made no improvement in the results. At any rate, the continuance of an operation carrying such an astounding mortality after such an exhaustive trial, was impossible.

The reaction came with the publication, in 1917, of Cushing's (5) important monograph on acoustic tumors, and with it a revolution in treatment. He accepts the only conclusion which the foregoing results and experiences of his own could justify, i.e., "I doubt very much, unless some more perfected method is devised, whether one of these tumors can with safety be totally enucleated." He no longer attempted to enucleate these tumors totally but was content to offer a method by which the tumor could be partially removed (intracapsular enucleation).

Cushing's contribution is the only important advance in the treatment of cerebellopontile tumors. For the first time the patient was offered a relatively safe surgical procedure with prospects of temporary relief and prolongation of life, in lieu of a hazardous and desperate effort carrying permanent disability in the wake of the very occasional chance recovery. In the first series of operations his mortality rate was reduced to 35 per cent, and in a subsequent series of about equal number to 11 per cent.

But intracapsular partial extirpation is far from satisfactory, for the growth must always recur. Partial removal of the tumor, even when the growth develops slowly, can never be considered a final operation for a potentially benign tumor.

THE DEVELOPMENT OF AN OPERATIVE PROCEDURE FOR THE TOTAL REMOVAL OF CEREBELLOPONTILE TUMORS

The purpose of this communication is to present an operative procedure by which it has been possible to remove the entire cerebellopontile tumor in a group of cases. Admittedly, it is a procedure of magnitude and carries potentialities of great danger. However, with care and attention to detail the mortality may not be greater, and not improbably even less, than Cushing's partial intracapsular enucleation. The method has been gradually evolved from the failures of other operative procedures. Finally it was forced upon us in an effort to avert an impending death several days following the partial (intracapsular) operation.

Our operations on cerebellopontile tumors cover the past 9 years. At the present writing the series consists of 23 tumors, the results of which are included in Table I under the various methods of operative attack. One case, apparently well on admission, died at stool a few hours before the time scheduled for operation. In a general way the order of the grouping is also chronological, though this is not strictly true. Our operations began at a time (1915) when the results of attempted enucleations were known, but our efforts were necessarily directed along the more or less generally recognized methods of operative attack. The initial attempts at a simple suboccipital decompression met a sharp and entirely unexpected reverse and dispelled at once our pre-existing im-
Fig. 1. An example of the characteristic cerebello-pontile tumor showing the extent to which the brain stem is excavated by the neoplasm. The intimate relationship with the medulla and pons explains the great danger which has attended all efforts at removal.

pressions of the value of this procedure as a palliative measure. Two cases so treated died within 12 hours, postmortem examinations revealing no hemorrhage or other cause in either instance. Al-though the intracranial pressure was well advanced in both patients, each was conscious and in good physical condition at the time of operation. Disregarding for the moment the explanation of these deaths—now better understood—it is at least evident that this comparatively simple procedure has been accompanied by great danger and has in nowise helped to solve the problem of removing the tumors.

In desperation, our next effort, total extirpation with the finger at one stage, then seemed the only alternative. It was, of course, merely a reversion to the well tried and fruitless method of Horsley, Krause, Eiselsberg and others. Nor was there reason to expect better results. After two initial successes, four deaths in succession showed the futility of further attempts. It is of little concern that one case is well 5 years later, and the fate of the other after leaving the hospital is unknown. The results are of interest and importance only in that their careful analysis did explain the causes of death and therefore suggested methods of avoiding them.

At this time of despair, Cushing's method of intracapsular enucleation was introduced. Its great improvement over other procedures was at once obvious. Despite enthusiastic hopes, however, our first experiences with intracapsular enucleation were unfortunate in being less satisfactory than had been anticipated. Following an uneventful and quick recovery from the effects of the operation, the first patient 7 days later became listless and drowsy; vomiting, dysphagia and dysarthria appeared; and during the succeeding 3

Fig. 2. Necropsy specimen showing the bed of the tumor after the capsule had been carefully removed. At operation the interior of the tumor had been removed and the patient died subsequently of meningitis. The marked excavation and destruction of the side of the pons and mid-brain is shown; also the fifth nerve intact.
days all symptoms became progressively worse and finally alarming. The late appearance of these symptoms seemed to exclude the postoperative complications which might have been expected, haemorrhage or infection, and suggested that in some way the reaction about the stump of tumor which remained was responsible for the condition. The wound was reopened and the shell of tumor extirpated with the index finger. There was surprisingly little haemorrhage, which was readily controlled. The patient’s condition then steadily improved. Diminished drowsiness was at once apparent, the vomiting at once ceased, and 5 days later she was able to swallow. From the result of this case it seemed logical to infer that if the shell of the tumor could in some way be removed at the first operation, this stormy and dangerous course following subtotal removal might be avoided. In the succeeding cases in which the tumor has been

<table>
<thead>
<tr>
<th>Kind of Operation</th>
<th>Number of Cases</th>
<th>Recovery</th>
<th>Death</th>
<th>Cause of Death</th>
</tr>
</thead>
<tbody>
<tr>
<td>No operation</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>Died at stool before time set for operation.</td>
</tr>
<tr>
<td>Patients in coma at time of operation (intracapsular enucleation and dissection of capsule)</td>
<td>2</td>
<td>0</td>
<td>2</td>
<td>Operation.</td>
</tr>
<tr>
<td>Suboccipital decompression. (Tumor not removed)</td>
<td>2</td>
<td>0</td>
<td>2</td>
<td>Operation.</td>
</tr>
<tr>
<td>Tumor shelled out with finger (interior not removed)</td>
<td>6</td>
<td>2</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Intracapsular enucleation</td>
<td>3</td>
<td>1</td>
<td>2</td>
<td>Both died of meningitis, one on the 46th, the other on the 4th day.</td>
</tr>
<tr>
<td>Intracapsular enucleation followed by finger enucleation of the tumor: 3 cases in 2 stages, and the fourth in one stage</td>
<td>4</td>
<td>3</td>
<td>1</td>
<td>Pneumonia, 8th day.</td>
</tr>
<tr>
<td>Intracapsular enucleation followed by deliberate, painstaking dissection of the capsule (all concluded in one stage)</td>
<td>5</td>
<td>5</td>
<td>0</td>
<td></td>
</tr>
</tbody>
</table>
removed at one sitting, the results have amply supported this inference.

THE OPERATION (6)

Needless to say, the success of this procedure is dependant not only upon many technical advances which have been slowly accumulating, but also upon a clearer understanding of intracranial physiology and pathology. Without Horsley's bone wax or Cushing's silver "clips," without Horsley's principle of decompression to take care of postoperative traumatic edema, without the bilateral cerebellar exposure (probably originated by Cotterill, 4) which allows more room for exposure and for decompression, and finally without Cushing's intracapsular method of removing the body of the tumor, the removal of the capsule of the tumor could hardly be accomplished.

A bilateral cerebellar approach, which has be-

Fig. 6 (left). Another patient 18 months after extirpation of tumor, showing good return of facial function after spino facial anastomosis.

Fig. 7. Showing the right facial movements which have returned after total removal of a right cerebello pontile tumor. Elevation of the shoulder brings out the maximum effect due to the associated movement.

Fig. 8. Fragments of tumor removed by intracapsular method. The large mass is the upper pole which projected through the incisura tentori. This is the most inaccessible and, from the standpoint of relief, the most important part of the tumor; upon its removal depends the release of the occluded aqueduct of Sylvius. In later cases the interior of this pole has been more thoroughly curetted, making the capsular removal easier and safer.

come more or less a regular practice for all cerebellar lesions, is first made and the bony and dural defect extended laterally and superiorly on the side of the tumor as far as the transverse and lateral venous sinuses will allow (Fig. 11). Because of the great depth of the tumor, an ordinary bilateral cerebellar approach alone would not afford the direct inspection and lengthy manipulation which is necessary to dissect the growth from its bed. Indeed, in a survey of Cushing's cases, there are instances in which the tumor was missed at the first operation because of insufficient exposure, and there are other cases in which the tumors were found only by transecting the cerebellar lobe. Attempts to expose the tumor with an insufficient removal of bone causes serious injury to the brain from retraction. Always the mastoid cells are brought into view, but unless the easy exposure of the tumor makes imperative demand, their entrance is avoided. But when opened the cells are at once covered either with a sheet of wet cotton or by reflected dura (Fig. 12) which is sutured to the galea or trapezius muscle. The history of a mastoid infection would give great concern, and every other possibility of the tumor's exposure would be attempted before yielding to an easier approach which opening hitherto infected cells would provide. The anterior part of the bony extension is carried under the attachment of the trapezius muscle but the continuity of this
Fig. 9. Grouping of fragments of the tumor removed by the curette. By drawing the capsule forward the interior of the tumor can be deliberately curetted for the brain stem is always exposed to view. The size of the extirpated fragments then becomes more uniform.

Muscle with the galea is carefully preserved. A good exposure of the entire superior surface of the cerebellum is important in providing a good exposure of one large vein (Fig. 11) which bridges the space between the superior surface of the cerebellum and the tentorium which it enters en route to the transverse sinuses. Unless ligated and divided beforehand, this vessel may easily be stretched and torn in elevating the cerebellar hemisphere and in exposing the tumor. There is less danger of such injury to the contralateral symmetrical vein, and similar precautions against its injury are not necessary. Needless to say, special care is taken to avoid incising either the lateral or sigmoid sinuses, particularly the latter.

Almost without exception, the dura has been so tense that it has been necessary, or at least advisable, to relieve pressure in the dilated ventricles, tapping and withdrawing fluid from the posterior horn of a lateral ventricle. Hydrocephalus

Fig. 10. Roentgenogram (anteroposterior view) showing cluster of silver clips, each representing a ligatured vessel. They also demonstrate how nearly the tumor approaches the midline.

Fig. 11. The bony defect of the usual bilateral cerebellar approach is considerably enlarged on the side of the tumor, as far as the transverse and lateral sinuses. The exposed dura on the right indicates the additional bony removal obtained in this way. Incision of the dura along the dotted lines affords much additional room for exposure of the tumor.
invariably results when the tumor has occluded the iter (Fig. 3), and few tumors appear for operation before this phase of the tumor's progress is well established. Before removing the ventricular needle, gentle pressure can, if desired, be applied to the intact dura and additional relief of pressure which is exerted upon the posterior fossa will follow the further escape of fluid which is afforded by the upward push of the tentorium. In every case of hydrocephalus from cerebellar lesions, the intracranial pressure above the tentorium can be reduced to that of the atmosphere by this simple expedient and without danger of injury to the brain stem.

After this preliminary measure, gentle elevation of the cerebellar lobe quickly brings the tumor into view, though at a great depth (Fig. 12). Another invariable finding in all cases of cerebellopontine tumors is the partial or complete obliteration of the cisterna magna, the cerebellar tonsils projecting through the foramen magnum into the spinal canal (Figs. 11 and 12). If, however, the cisterna does still contain fluid, its release again contributes that much more room to the all-important exposure of the tumor. An encapsulated bed of fluid (having no communication with the subarachnoid spaces) may or may not crown the outer and superior surfaces of the tumor and, though largely or entirely obscuring the tumor, its presence is almost as characteristic of an underlying cerebellopontile tumor as the direct inspection of the neoplasm itself. Further elevation of the cerebellum brings the unattached outer surface of the tumor into full view and into a position where it can be subjected to an operative attack. Excepting the poles which have passed beyond the confines of the posterior cranial fossa (through the incisura tentorii and the foramen magnum), the entire longitudinal extent of the tumor is brought into full view. The capsule is then incised longitudinally from pole to pole (Fig. 12) and much of the outer contents removed piecemeal with a curette after the method of Cushing (Fig. 13). The capsule is then picked up at the margins of the opening in the tumor, drawn forward with forceps, and the attached surface of the capsule brought into view (Fig. 14). The contents of the tumor are then curetted with the brain stem and cerebellum always fully exposed. Continuing this method, the capsule gradually becomes thinner and when drawn forward permits inspection of the cleavage line between the brain stem and capsule of the tumor. When the poles of the tumor have invaded the middle cranial fossa and the spinal canal, removal of their interior allows them to be easily withdrawn into the posterior fossa; such polar extensions of the tumor are least adherent to the brain stem. Gradually in this way the entire capsule is separated from the brain stem. As the capsule is cautiously retracted, several small blood vessels crossing from the brain stem or cerebellum are brought into view and doubly "clipped" and the vessel divided. Practically all bleeding can be forestalled in this way (Fig. 10).

Removal of the capsule of the tumor in this way is necessarily very tedious and time consuming. The method employed is but the application of the fundamental surgical teachings of my former chief, the late Professor Halsted. By this great master every operation, whether unusual or commonplace, was performed with the utmost care. All tissues were handled with the greatest gentleness, the field unstained with blood, and a step was never taken blindly. Always his work was painstaking, the field of operation immaculate, and hemorrhage minimal. Time of operation was
always subordinate to accurate and thorough performance.

It is clear that as a measure preliminary to removal of the capsule, the intracapsular curettage must be carried out much more thoroughly than when this procedure is the end-result. When the tumor is curetted blindly, i.e., with only the outer aspect of the growth in view, the total amount of tumor removed, though seemingly great, will be relatively small, for the danger of penetrating the capsule and injuring the brain stem with the curette is always uppermost in the operator’s mind, and in avoiding this possibility it is more probable that too little rather than too much will be removed. The more thoroughly the capsule is stripped of its solid contents (up to a certain limit), the easier becomes the final stage of its separation from the brain stem. It should not be inferred that the separation of the capsule is not attended by difficulties. It is always difficult and frequently for some time seems impossible. Only by persistently tugging at the capsule, often gaining but a millimeter at a step, does its attachment finally yield.

In one of the earlier cases the ultimate release of a fraction of the capsule seemed impossible of accomplishment and was given up. It is quite probable that with increasing experience and confidence this capsule could now be removed. On the other hand, only quite recently the capsule in another case was so delicate that at every attempt at traction it tore and when there seemed no way to overcome this difficulty in desperation the capsule was shelled out with the index finger. There is, however, a marked individual difference in the degree of attachment of the tumor to the brain stem, and there will probably always be instances in which a deliberate and painstaking removal will not be possible.

When the capsule is ultimately delivered, the denuded brain stem should and must be perfectly dry. A fatality will almost surely ensue if even the slightest ooze persists when closure is begun. Drainage has usually been avoided, though in two instances a rubber protective wick was placed in the lateral recess and removed in less than 24 hours.

The largest vessels encountered during the operation are the postero-inferior cerebellar and vertebral arteries which wind around the lower pole of the tumor and usually one and at times two branches to the tumor are given off from the former. These arteries are but loosely attached to the tumor and can easily be stripped from it after the branches have been divided. At the other pole of the tumor is a large venous branch of the inferior petrosal sinus. Closely applied to the tentorium and the tumor, from which it emerges, this vein may be very troublesome unless dissected free, ligatured and divided in the operation. Naturally the vessels causing greatest concern are the arteries which cross from the brain stem to the tumor. There are usually three to six of these vessels in addition to two or three from the inferior surface of the cerebellum. Though constituting probably the greatest danger of the operation, there is, however, no great difficulty either in exposing or ligating these vessels.

Removal of the tumor at a single stage is undoubtedly far preferable to two stages. Despite its
great length (often 3 to 4 hours) the operation is usually well borne, and unless exceptionally difficult can be completed before lowering blood pressure or accelerating pulse gives warning of danger. Only once did the patient's condition necessitate abandoning operation and continuing at a second attempt. In three cases the capsule was intentionally left for a second stage (7 to 12 days later). In the interim the capsule had become so soft, swollen, and friable that the teeth of the forceps were no longer able to retain a grip and the capsule then had to be shielded out with the finger. If the capsule cannot be carefully extirpated at the first stage, its enucleation with the finger can undoubtedly be accomplished with greater safety at a second and not too distant stage, for the oedema of the tumor which remains, doubtless reduces the caliber of the small arteries supplying it and greatly modifies the bleeding.

It is not the purpose of this communication to commend finger enucleation for these tumors. However, in those exceptional cases in which the capsule of the tumor cannot be liberated, I believe the removal of the capsule at a second stage to be superior in the ultimate, and at times in the immediate results, to the subtotal intracapsular enucleation alone. An excellent example of this impression is given in the patient previously mentioned. When, several days after intracapsular enucleation, stupor, vomiting, dysphagia, and dysarthria appeared and progressively increased, not only did she promptly recover and the symptoms quickly disappear after enucleation of the capsule with the finger, but she has since remained as well as any of those patients in whom the operation was completed by careful dissection in one stage.

The bond between the brain stem and tumor may be solely by connective tissue, but in one case at least the tumor has been found at necropsy to be a direct outgrowth of the brain stem (Fig. 3). It can hardly be denied that when the tumor is actually continuous with and a direct outgrowth from the brain stem its origin must be from the brain stem and not from the region of the porus acusticus, as has been claimed. But the origin of these tumors is another story which we shall consider at another time. The capsule has always been most adherent at the pons; in the single case in which a line of cleavage could not be followed throughout, the fragment of tumor remained tightly adherent at the pons.

Cerebellopontile tumors are only slightly adherent to the dural covering of the base of the skull, but the separation of the capsule nearly always leaves an oozing, raw surface, and at times an even greater degree of bleeding. At the porus acusticus, however, the attachment is always firm for the auditory nerve is an integral part of the tumor. This attachment has usually been liberated after the tumor has been separated from the brain stem, but in one case the dissection was begun at the meatus and in so doing it was possible to pick up and follow the facial nerve in the capsule, in which it was superficially located, to the brain stem. But in liberating the capsule from the pons, the nerve was accidentally torn. Greatly elongated by its stretch around the tumor, the facial nerve in this case was a very delicate filament scarcely larger than an ordinary cambric sewing needle. In none of the other cases has the facial nerve been seen during dissection of the tumor. Should preservation of the facial nerve with total removal of the growth be ultimately possible, it could doubtless be more easily located at the internal auditory meatus. Its course is probably always, as in this case, on the under surface and toward the lower pole of the tumor.

The trigeminal nerve is always brought clearly in view during the dissection and throughout its intracranial course (Fig. 15). Usually it first appears when the upper pole of the tumor is withdrawn from the incisura tentorii or separated from the tentorium. But on one occasion when the dissection from the inferior pole proceeded with unusual ease, the nerve was first exposed at its junction with the pons; its exposure was then continued forward in the direction of the mid-brain. Being tightly squeezed between tumor and brain stem which it parallels (Fig. 2) the trigeminal nerve has been flattened like a ribbon. Its more distal course is determined by the upper pole of the tumor which pushes the nerve ahead, oftentimes into the middle cranial fossa, causing it to double back upon itself before entering the dural envelope surrounding the gasserian ganglion.

The remaining cranial nerves of the posterior cranial fossa (on the side of the tumor), though pushed aside and even somewhat elongated by the tumor, are much less seriously affected. Before the dissection is started, the spinal accessory nerve, most affected of this group, is often seen bending around the inferior pole of the tumor from behind, but in any case it is quickly brought into view when the inferior pole is drawn forward. The vagus and glossopharyngeal nerves appear in succession when the inferior pole is drawn a little farther forward. Never more than lightly attached to the growth, these nerves are pushed mesially and inferiorly, the distortion of each depending upon the size and configuration of this part of the tumor. In one case a tumor nodule projected between the spinal accessory and vagus nerves. The hypoglossal nerve, having a more mesially placed exit, is less disturbed by the tumor. This entire group of nerves fall away as the capsule of the inferior pole is dislodged (Fig. 14). Although the basilar artery has been exposed on two occasions, I have never recognized the abducens nerve.

We have carefully examined every porus acus-
ticus after extirpation of the tumor, but in only two instances was there an appreciable widening of this opening. Not infrequently there was a rather diffuse concavity of the region surrounding the meatus, and in one instance a quite deep pit (about 1 by 1 centimeter and probably 3 millimeters deep) with fairly abrupt walls extended mesially from the porus and included its inner margin, but the outer margin remained unchanged. These findings explain the lack of positive changes in roentgenograms and they also constitute evidence against the theory of origin of the tumor in the internal auditory meatus. When the tumor has extended into the porus, its liberation has not been difficult. Only on one occasion was it necessary to chisel away the outer margin of this opening before this dissection could be completed.

With one exception the operations have been performed under ether anesthesia. Novocain worked admirably in this exception until the brain stem was reached, when the pain became so severe that ether was given for the capsular dissection. The patients are maintained in the horizontal face-down position. Pulse and blood pressure readings have been the best criteria of the patient’s condition and largely determined whether the operation could be concluded in one or two stages.

**Postoperative Course**

Few brain tumor extirpations run a more uneventful and satisfactory course than these have done. Without exception, the patients have quickly become conscious, have remained so, and on the following day have appeared free of danger. That two of the series of total enucleations should have survived a superimposed purulent meningitis (streptococcus viridans and staphylococcus aureus), the symptoms of which appeared 48 hours after the operation, indicates the rapidity of recovery from the operation. The postoperative temperature curves of these patients are more or less uniform. The rectal temperature slowly rises to a maximum which is usually reached in 10 or 12 hours, and it almost as quickly descends to a level around 101 or lower the next morning. Usually the maximum temperature is about 103.6 to 104.2, though one case reached 104.8. At the end of the operation when the patient is coming out of ether, the quality of the pulse will be at its worst and the rate highest. Despite the gradual postoperative rise of temperature, the patient remains conscious and the pulse slowly falls, usually reaching 100 to 120 on the following morning.

Of the series of 5 cases in which the capsule was carefully removed (all in one stage), postoperative dysphagia was present in only one patient, and she had been unable to swallow for 36 hours before the operation. Five days later nasal feedings were discontinued. In all of the four cases in which the capsule was enucleated with the finger, nasal tube feeding was necessary, but in two of these patients inability to swallow had developed 7 and 10 days after a subtotal intracapsular enucleation (first stage) and was therefore not caused by the operation. The one death in this series was from pneumonia (eighth day) and was doubtless induced by aspiration during this period when swallowing was difficult. Surely this death could now be avoided. Fluids are now withheld from patients after operation until they are well able to swallow; in the interim the regular nasal feedings are substituted.

Each of the five cases was able to walk out of the hospital with support, and to some extent alone, the time of departure being 16, 18, 18, 25, and 76 days after operation. One patient was unable to walk when she entered the hospital because of a partial hemiplegia (there was also dysphagia) resulting from the tumor's indentation of the brain stem; 23 days after the operation she walked across the room without support. The protracted stay of the patient who remained in the hospital 76 days was due to a postoperative streptococcus viridans infection, which was cured by cisternal drainage. Fortunately this patient has retained no ill consequences of the infection.

**Subsequent course of patients after removal of tumor**

There has as yet been no recurrence, but the longest time since operation has been only 3½ years. Every patient is well, free from headache, and has been able to return to work. The one outstanding sacrifice of the operation is the hemifacial paralysis (Fig. 4). It has as yet been impossible to preserve the facial nerve, though I am not so sure that this may not eventually be possible. The reason for this hope is that in one case (previously mentioned) the facial nerve was dissected from the porus to the pons but was finally inadvertently torn when the capsular dissection was continued. The patient is informed of the necessary loss of the facial nerve beforehand and is given the choice of an intracapsular curettage of the tumor. With a spinofacial or hypoglossofacial anastomosis, however, the degree of this deformity has been greatly modified (Figs. 5 and 6). Six of the 8 patients have had spinofacial anastomoses and all with returning function. Before attempting an anastomosis, the function of the spinal accessory or hypoglossal nerves must be tested in order to preclude union with a nerve trunk which may have been injured at the time of operation.

The auditory nerve, being incorporated in the tumor and totally paralyzed before the operation, is irretrievably lost. This, of course, holds equally true when intracapsular enucleation is performed.
The trigeminal nerve has been injured at operation in each of the 5 cases, but sensation has returned to a more or less degree in every instance. In the three finger enucleations, the trigeminal function has been destroyed in two and only injured in the third. Ulceration of the insensitive cornea is a danger which must be guarded against by shielding the eye. In one of the eight cases enucleation of the eyeball was finally necessary, and in another vision in the affected eye was lost following healing of the ulcer. The danger of this complication is the same as that following resection of the posterior root of this nerve for tic douloureux. With the improved methods of prevention now in vogue, corneal ulceration should become a less disturbing factor.

In every case there has been dizziness and consequently balance of the body has been disturbed, but always there has been a steady and progressive improvement. It is probable that this disturbance may be the result of retracting the cerebellum—a factor which should be lessened as our skill in removing the capsule improves. A very slight weakness and stiffness of the hand on the homolateral side has persisted in 6 cases, and in two recent cases (2 and 6 months) after finger enucleation of the capsule the affection is more pronounced. Soon after the operation there has at times been some slight subjective stiffness of the corresponding leg, but this has soon entirely disappeared except in the above two cases of finger enucleation. Doubtless this slight residual disturbance is the result of injury to the pyramidal tracts in the brain-stem, and for this reason the arm fibers presumably are situated more externally than the fibers for the leg.

Table II indicates in a general way the results obtained in these patients to date. While the time is too short to refer to the absence of recurrence, the encapsulated character of the tumor and its total removal should leave little doubt that they will not recur. It may again be emphasized that the determination of the total removal of the tumor is not by guesswork but by a careful inspection of the site of the growth at the end of the operation. It is at once evident that the results following finger enucleation are incomparable (excepting 1 case) to those following painstaking removal of the capsule.

EXPLANATIONS OF THE MORTALITY FROM VARIOUS PROCEDURES

At first glance it must seem incredible that the total removal of a cerebellopontile tumor can be accomplished with even less mortality than that following the relatively simple curettage of only part of the tumor's interior. It cannot be reasoned that because an operation is simpler, it is better and safer. The simplest operation for these tumors is a cerebellar decompression, but it has been attended by the highest mortality in the hands of nearly every operator. The reason for these seemingly paradoxical results is the simple one of cause and effect. If the patient's condition will justify the additional effort, there is no relief so quick and so complete as that following removal of the cause. There are occasions when the effects of the cause can be relieved by a smaller and less dangerous palliative operation (decompression), but that is only true at times. There are many intracranial tumors which can never be even slightly benefited by any form of palliative procedures, and under such conditions the procedure itself becomes an insult added to an already overstrained intracranial pressure. Cerebellopontile tumors offer seemingly insuperable obstacles to the success of the customary palliative operations in the late stages of the tumor's effects.

The high mortality from the simple enucleation of cerebellopontile tumors with the finger or spatula is now readily understood. Death results from injury to the brain stem when the finger tears the tumor from the brain stem and from packing the denuded brain stem in the frantic efforts to check hemorrhage. An examination of the brain after death in one of our cases showed the lateral margin of the brain stem softened and minute hemorrhages extending almost to the midline in the pons and medulla. This finding is not surprising since immediately after the tumor is shelled out there are always symptoms and signs which serve as telltale indicators that the medulla has been injured. At once respirations cease for many seconds (often a minute or more), after which they reappear irregularly and with serious embarrassment, and after several minutes they usually become more or less normal. However, after a severe injury the respirations may remain irregular, difficult, and ineffective, or apparently they may even fail to reappear, though it has never occurred in our cases. But even when the respirations seem to have become satisfactorily re-established, a secondary phase of embarrassment is almost sure to reappear 4 to 8 hours later. It seems probable that this may be a secondary reaction (edema) of the tissues to the initial trauma. This phase of secondary reaction is characterized by harsh, slightly irregular, and more rapid respirations; the pulse rate accelerates and diminishes in volume, the temperature rises steadily, the reflexes diminish and the patient becomes progressively more difficult to arouse. Obviously precisely the same effects are produced when the brain stem is compressed by hemorrhage.

Why is there such a high mortality following a simple suboccipital decompression in the presence of cerebellopontile tumors? It would often be a great comfort to be able to do a simple bilateral suboccipital decompression and complete the re-
TABLE II.—END-RESULTS

CASES WITH RECOVERY AFTER CAREFUL REMOVAL OF CAPSULE

<table>
<thead>
<tr>
<th>Age</th>
<th>Time since Operation</th>
<th>Gait</th>
<th>Balance</th>
<th>Arm and leg on affected side</th>
<th>Ramberg</th>
<th>Aetadms</th>
<th>VN</th>
<th>Headaches</th>
<th>Wt.</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>MBW</td>
<td>49 yrs.</td>
<td>1 yr.</td>
<td>Walks 1.5 miles per day</td>
<td>Still feels dizzy but is improving</td>
<td>Leg well, Arm and hand stiff</td>
<td>Slight</td>
<td>Neg.</td>
<td>Sensation felt but less acutely</td>
<td>None</td>
<td>+10</td>
</tr>
<tr>
<td>TH</td>
<td>56 yrs.</td>
<td>1 yr.</td>
<td>Walks well</td>
<td>Slightly dizzy</td>
<td>Stiffness hand, Leg normal</td>
<td>Slight</td>
<td>Neg.</td>
<td>Not normal but present</td>
<td>None</td>
<td>-10</td>
</tr>
<tr>
<td>EB</td>
<td>44 yrs.</td>
<td>1 yr.</td>
<td>Can walk 4 miles without support</td>
<td>Still slightly affected but gradually disappearing</td>
<td>Hand still slightly affected</td>
<td>Neg.</td>
<td>Neg.</td>
<td>Patch of anesthesia below eye</td>
<td>None</td>
<td>+8 to +15</td>
</tr>
<tr>
<td>JM</td>
<td>29 yrs.</td>
<td>11 yrs.</td>
<td>Except narrow plank or down steep grade, can walk anywhere without support</td>
<td>Practically normal</td>
<td>Still slight weakness of arm; leg normal</td>
<td>Slight</td>
<td>+</td>
<td>Some loss but sensation present</td>
<td>None</td>
<td>-25</td>
</tr>
<tr>
<td>IR</td>
<td>36 yrs.</td>
<td>1 yr.</td>
<td>Can walk a mile without support</td>
<td>Still feels slightly uncertain</td>
<td>Very slightly less than normal</td>
<td>Neg.</td>
<td>Neg.</td>
<td>Not quite normal</td>
<td>None</td>
<td>Same</td>
</tr>
</tbody>
</table>

CASES WITH RECOVERY AFTER INTRACAPSULAR ENUCLEATION FOLLOWED BY FINGER EXTRAPARATION OF CAPSULE

| EL  | 25 yrs. | 2 yrs. | Can walk any distance alone | Only occasional loss of balance | None | Very slight swayling | Neg. | Normal about lower face; diminished above | None | +15 | Two-stage operation. |
| RLB | 48 yrs. | 6 mos. | With support can walk briskly, but requires help except in house | Very marked difficulty in balancing | Good grip but quite shaky | Markedly positive | + | Sensation absent | None | +60 | Ulcerated eye removed. Hearing much better. Smallest tumor of series but symptoms of 20 years. |
| WD  | 23 yrs. | 2 mos. | On discharge from hospital can walk with support. Pt. has been 2 months recuperating from meningitis and a resultant hydrocephalus | Very marked difficulty in balancing | Markedly affected | Markedly positive | + | Sensation absent | None | -10 | Postoperative meningitis (staphylococcus aureus); cisternal drainage; resulting hydrocephalus cured spontaneously. Largest tumor of series, wt. 45 gms. Two-stage operation. |

NOTE.—As all of the patients live at a distance, this table is compiled from answers to letters of inquiry. Six of the eight cases have had spinofacial anastomoses with returning function in each instance.
Cerebellopontile tumors not only deeply indent the brain stem (reducing its bulk as much as one-fourth or even more) but dislocate it to the opposite side causing its normal straight mid-axial line to become a pronounced curve. But this great defect and alteration in the brain stem are tolerated because the changes have been so gradual. It is even remarkable that no appreciable disturbance of function can usually be detected by our clinical tests.

Most cerebellopontile tumors are small in comparison with cerebral tumors or even with other tumors in the posterior cranial fossa. Although the posterior compartment is small, the actual bulk of the tumor is not difficult of compensation by (1) partial obliteration of the cisterna magna, the cisterna pontis, the cisterna beneath the mid-brain, and the fourth ventricle; (2) herniation of the tonsils of the cerebellar lobes into the spinal canal (through the foramen magnum); and (3) by pushing the tentorium cerebelli upward. Were it not for a new factor which inevitably supervenes as the tumor grows, life could doubtless be maintained for a much longer time by these adjustments. This new factor is closure of the aqueduct of Sylvius. When this small channel becomes closed by the anterior extension of the tumor, hydrocephalus involving the third and both lateral ventricles inevitably results. It is only with the onset of hydrocephalus that the real intracranial pressure develops. The pressure caused by the hydrocephalus always develops rapidly and soon overcomes the space adaptations which had previously been consummated in the posterior cranial fossa; it also quickly reduces to a minimum nature's remaining reserves of space compensation. Though quite firm, tough, and inelastic, the tentorium cerebelli is gradually pushed backward reducing the space in the posterior cranial fossa. These qualities of the membrane, however, must be of great service in temporarily protecting the contents of the posterior cranial fossa, and to the tentorium is doubtless due the preservation of life pending the advent of surgery. Without doubt the danger of cerebellar decompression is proportionate to the degree of hydrocephalus which is present at the time of operation.

What happens when the occipital bone is removed and the dura opened widely—cerebellopontile decompression? Removal of the occipital bone at once liberates the pressure in the posterior cranial fossa. But this benefit is at once counteracted, and may be greatly exceeded, by the injurious effects of the backward pressure on the tentorium (hydrocephalus) and its full force is now exerted without opposition upon the delicate brain stem jamming it backward. It would seem that this force must be exerted almost entirely through the incisura tentorii for the tentorium itself would hardly be sufficiently elastic to stretch so quickly as to produce these disastrous results.

It must not be inferred that the results following suboccipital decompression are the same for all tumors in the posterior cranial fossa. Variations result from differences in the character, position, and fixation of the tumor. Almost complete relief of all symptoms will at once follow suboccipital decompression when a cerebellar cyst is evacuated. And oftentimes even when a cyst has not been evacuated or an intracerebellar tumor not removed, the same complete but temporary relief will be obtained, for the backward dislocation of the tumor may be great enough to relieve the obstruction at the aqueduct of Sylvius. But cerebellopontile tumors (and some other growths in the posterior fossa) are so firmly fixed to the floor of the skull that dislocation of the tumor cannot occur. Therefore, no relief of the hydrocephalus can be expected from decompression. Moreover, these tumors nearly always extend from one end of the posterior fossa to the other, and are closely attached to the brain stem throughout. Indeed, as noted before, they often extend posteriorly through the foramen magnum into the spinal canal and anteriorly through the incisura tentorii, even at times far enough anteriorly to destroy the posterior clinoid process. Not infrequently, however, a relatively small cerebellopontile tumor produces more severe and fulminating manifestations of intracranial pressure than larger growths because a small projecting nodule of the tumor imbeds itself deeply into the side of the mid-brain, causing the aqueduct of Sylvius to be obstructed.

There can be no doubt that many obstructions of the aqueduct and fourth ventricle have a ball-valve action. This can be shown by the fact that at one time the intraventricular pressure will register very high, on a succeeding day it may be normal. In fact, one can easily be misled into assuming the absence of a neoplasm by finding a normal intraventricular pressure; the pressure may be low owing to the particular stage in the cycle of changes resulting from the ball-valve action of the tumor. Such vacillations in pressure are impossible in tumors which have infiltrated the aqueduct; they are most frequent in mobile non-infiltrating tumors; and are of intermediate frequency in fixed non-infiltrating tumors such as the cerebellopontile group. Periodical relief from
pressure of this character is doubtless less frequent in occlusions of the aqueduct than of the fourth ventricle because the channel of the iter is so narrow.

It does not seem possible that the hydrocephalus could be relieved by any lateral diastole of the brain stem away from the tumor in the tentorial opening, for usually the tumor has filled the superfluous space in the incisura tentorii, at least in the lateral aspect; and any anteroposterior dislocation of the brain stem can hardly have any effect other than to make any partial obstruction of the iter complete.

The injury resulting to the brain stem from the supratentorial pressure probably bears a close analogy to that following two other well-recognized procedures, often erroneously considered harmless. Severe medullary embarrassment and even death are not rare sequels of a lumbar puncture performed in the presence of high intracranial pressure. Death or other injurious effect in these cases is surely due to the injury inflicted upon the brain stem when by the release of the intracranial pressure the cerebellar tonsils are suddenly driven more deeply through the foramen magnum into the spinal canal. One of the patients in our series was in coma from this ill-advised procedure.

The other example of the danger of disturbing established pressure relations is shown when lumbar punctures are performed in the presence of certain spinal cord tumors. In a not inconsiderable percentage of cases, sensory and motor function and sphincter control will be quickly affected, even lost, after lumbar puncture (8). In nature's effort again to equalize intraspinal pressure after lumbar puncture in the presence of a complete spinal block, the higher pressure above the tumor can only spend its force by jamming the spinal cord against the inmobile tumor. Unless the tumor is situated in the high cervical region, these injuries to the spinal cord affect only function, whereas the analogous (though greater) effects of supratentorial pressure on the medulla in the presence of cerebellopontile tumors compromise life as well as function. We believe, therefore, that when the dural and bony support of the occiput is removed (suboccipital decompression), the supratentorial pressure pushes the brain stem backward through the incisura tentorii until its force is spent; also that this injury to the brain stem is probably augmented by the tug on the firmly fixed cerebellopontile tumor. The degree of this damage is probably proportionate to the grade of intracranial pressure and the size of the tentorial opening (the fixation of the tumor is probably fairly constant).

Why should a suboccipital decompression plus intracapsular removal (subtotal) of a cerebellopontile tumor be less dangerous than a suboccipital decompression alone? The fact that the mortality rate in these tumors has been reduced only by the advent of Cushing's intracapsular method of enucleation is ample evidence for the assertion contained in this interrogation. When the interior of the tumor is sufficiently removed, the capsule will be freed of its rigid support, thereby permitting the obstruction of the aqueduct of Sylvius to be released. The supratentorial pressure (of hydrocephalus), which is the real dangerous factor in these operations, will be automatically relieved as effectually for the time being as if the tumor were removed. But one of the greatest defects of subtotal intracapsular enucleation is the difficulty of removing the proper amount of the contents of the tumor to permit this benefit to accrue. Unless the tumor is thoroughly removed so as to leave a fairly empty capsule, the remaining tumor will be essentially as rigid and immobile as the original tumor, and there would then be little if any relief either to the laterally deflected brain stem or to the hydrocephalus. During the removal of the contents of the tumor with a curette, only the outer surface of the growth is brought into view and one has great difficulty in knowing, indeed it is usually impossible to determine, the depth of tumor which still remains imbedded in or projecting beneath the brain stem. The importance of this determination we have learned from completely shelling out the interior of the tumors, as our deliberate total extirpations now necessitate. Curetting the interior of the tumor with the brain stem in the background, necessarily demands caution and, in playing safe, usually more tumor remains than seems possible from the apparent size of the exposed stump. In one of our two-stage extirpations 18 grams of tumor was curetted away and we thought but little was left with the capsule. The remainder of the tumor, when removed at the second stage, weighed 26 grams!

Since hydrocephalus results from occlusion of the iter, and since hydrocephalus is one of the chief factors in the operative mortality, it is safe to infer that the part of the tumor demanding urgent excavation is the upper pole. Otherwise, the hydrocephalus cannot be relieved. One of Cushing's necropsy specimens (Case xix) shows the upper pole of the tumor practically untouched by the intracapsular removal.

The configuration of the tumor also has something to do with the amount of tumor in situ after a subtotal removal. Nodules may project into the brain stem from the inner side of the tumor. It has seemed that these deeply imbedded and invisible localized masses at times cause more symptoms referable to the brain stem and play a greater role in obstructing the aqueduct of Sylvius, than the big bulk of the tumor. The effect of the nodules will not be greatly, if at all, influenced by removal of the outer portion of the tumor with a curette.

Unless one is acquainted with the technical
steps in a bilateral cerebellar operation, it would be reasonable to question why the brain stem has not already been injured by the supratentorial pressure during the operation, when the dura is opened widely. This pressure, however, is always under control. Puncture of a posterior horn of a lateral ventricle is always utilized to reduce the supratentorial pressure to that of the atmosphere. The period of great danger to the patient when the hydrocephalus has not been relieved, is in the few hours succeeding the operation—when the intraventricular pressure is again re-established.

*Why should there be less mortality after subtotal intracapsular enucleation of the tumor plus removal of the remainder of the tumor, than from the partial removal alone?* From this series two deaths were surely impending about 2 weeks after partial intracapsular enucleation of the tumors and were finally prevented by removal of the remainder of the tumor at that critical period. The defects of the partial operation, therefore, really forced the total removal of the growth. In every case in which a subtotal intracapsular operation has been performed (6 in all, if those cases are included in which the intracapsular method was the first stage), the immediate postoperative course has been perfectly satisfactory. It has been several days later when the patient should have been out of danger that the alarming symptoms developed. In some way the stump of tumor caused the important functions located in the brain stem to be seriously compromised. We know from the gross appearance at the second operation that the stump of tumor which remained was swollen and friable—doubtless owing to nature's method of repair—but in all probability these same changes were also present in the contiguous brain tissue and were responsible for the symptoms. Whatever the exact explanation may be, complete subsidence of all symptoms at once followed extirpation of the residual tumor and capsule. No such complication has appeared in any of the cases (5) in which the entire tumor has been removed at one sitting.

A careful survey of the results after various operative attacks, brings us to one general conclusion: with proper care and attention to detail, that operation which at once removes the cause (other things being equal) not only carries the lowest mortality but at the same time offers incomparably the best immediate and permanent results.

**Operations on Patients in Coma From the Effects of Cerebellopontile Tumors**

There is one exception to the above generalization concerning the removal of the tumor, viz., patients in coma from this type of tumor.

I have excluded from the operative mortality of total extirpations, two patients who entered the hospital when totally unconscious and who were operated upon while in this state. One patient had been unconscious 8 hours, the other 3, when the operation began, and in each there was Cheyne-Stokes type of breathing. Furthermore, in the first instance the location of the growth was entirely unknown until determined by ventricular estimation. The treatment, if any, for such cases is, I believe, distinctly a different problem from that which obtains when patients are in coma from tumors situated elsewhere in the cranial chamber. When patients are comatose from intracranial pressure, it is often possible to restore consciousness by a palliative, properly placed decompression; and at times the tumor may even be safely removed while the patient is still unconscious, all of course depending on the depth and duration of coma and the location and character of the tumor. In many such cases it is incumbent and preferable only to relieve the intracranial pressure immediately and the removal of the tumor can await a second stage, if advisable.

But, as said before, coma from cerebellopontile tumors is not amenable to relief from any form of decompression. Even when the patient is quite conscious and in good condition, a suboccipital decompression is tantamount to a mortality in the advanced stages of intracranial pressure. The realization of the futility of operative palliation in these tumors urged the more radical attempt at removal of the tumor after first curing the interior. Despite the fact that the extirpation was easy and bloodless in both instances, consciousness was not restored, there was no relief, and death followed within a few hours. In such cases we are dealing with a brain stem already severely injured before the operation began and any operation entailing even the slightest additional injury (such as the removal of the tumor must necessarily exact), could not be tolerated, even with relief of the supratentorial pressure.

Whether the partial intracapsular procedure would ever be successful under such conditions, one can only conjecture. Realizing as we do now the underlying differences between the coma of these and other tumors, it would surely have been wiser to have desisted, though the results would hardly have been different. This particular phase of the problem seems very dismal from our present knowledge and experience. I fear some new and totally different line of attack must be evolved if any results are to be expected in such cases. One great difficulty in these comatose patients is the differentiation beforehand of the kind of tumor, though its location in the posterior fossa may be clear. For tumors other than the cerebellopontile variety (such as intracerebellar tumors), a cerebellar decompression would always be indicated and would frequently prove effective treatment. When the character of the tumor has been deter-
mined only by operation, one is faced with the problem of proceeding with operative treatment. And when patients in coma from the effects of cerebellopontine tumors have been subjected to operation, decompression alone will surely be fatal; one can hardly do less than perform the operation devised by Cushing, and surely not more.

SUMMARY

An operative procedure is presented which cerebellopontine (acoustic) tumors can be completely removed. After a thorough and carefully guarded intracapsular enucleation, the capsule of the tumor is painstakingly dissected from the brain stem.

REFERENCES