A Study of Perioperative Lumbar Cerebrospinal Fluid Pressure in Patients Undergoing Acoustic Neuroma Surgery

ABSTRACT—The objective of this study was to measure changes in cerebrospinal fluid (CSF) pressure and cerebrovascular hemodynamics following acoustic neuroma surgery. The subjects were 32 patients undergoing translabyrinthine or retrosigmoid excision of acoustic neuroma. CSF pressure and the amplitude of the CSF pressure pulse wave were measured using lumbar catheters, and all variables were recorded minute by minute on a microcomputer. Transcranial doppler (TCD) was used to measure flow velocity in the middle cerebral artery in 10 patients to monitor changes in cerebral hemodynamics. In the 24 hours after surgery, all patients showed a statistically significant rise in CSF pressure from 11.4 mm Hg (standard deviation [SD] 6.1) to 19.6 mm Hg (SD 5.2) and a corresponding fall in the compliance of the CSF compartment. These changes were reversed within 48 hours, and the CSF pressure fell below the preoperative level over the next 4 days without any drainage of CSF. The results of this study demonstrate a transient increase in CSF pressure and decrease in craniospinal compliance that is provoked by surgery. The most plausible explanation for this disturbance is impaired CSF absorption, which resolves rapidly in most patients without therapeutic CSF drainage.

An important complication of acoustic neuroma surgery is the development of a CSF fistula. A fistula is a potentially life-threatening complication and results in a fivefold increase in the incidence of meningitis.¹ The incidence of CSF rhinorrhea or CSF leakage from the wound is approximately 15% in most major series and does not differ significantly between the translabyrinthine and retrosigmoid (suboccipital) approaches.

The usual path of CSF rhinorrhea following translabyrinthine surgery is from the posterior fossa

dural defect into the middle ear cavity. After retrosigmoid tumor excision CSF can leak from the cerebello-pontine angle into air cells that have been opened in the posterior internal auditory canal wall.² CSF can also leak through the dural repair into the mastoid air cells and into the middle ear. A wound leak results from a direct communication between the skin and the posterior fossa. In order to prevent the development of CSF fistula, surgeons have relied on meticulous wound closure and postoperative CSF drainage.³

Neurosurgeons have traditionally drained CSF after posterior fossa surgery in the belief that debris will be cleared from the subarachnoid space, that the risk of postoperative hydrocephalus is reduced, and that CSF drainage will reduce the risk of external fistula and pseudomeningocele formation by lowering CSF pressure. In the first 100 procedures for the translabyrinthine removal of acoustic neuroma performed in the Cambridge Otoneurosurgical Service, the CSF leak rate was 13%.⁴ By using a new technique of wound closure and by performing daily lumbar punctures, a dramatic reduction in postoperative CSF leaks to 1.6% in the subsequent 188 patients has been achieved.⁵ In this study, undertaken in patients undergoing acoustic neuroma surgery, lumbar CSF pressure and TCD flow velocities were measured in order to establish the usual sequence of perioperative changes in pressure and blood flow velocity. It was hoped that these observations would provide information concerning whether CSF drainage contributes to the success of the revised wound closure technique and whether CSF drainage should be continued in the management protocol.

METHODS

Subjects

A group of 32 consecutive patients (19 men and 13 women) undergoing excision of acoustic neuroma was studied. Their ages ranged from 45 years to 73 years, with mean age of 59 years. All patients underwent a full preoperative assessment, including magnetic resonance imaging (MRI). Two patients had intracanalicular tumors, 21 patients had tumors smaller than 2.5 cm, and 9 patients had tumors larger than 2.5 cm. Twenty-seven patients were operated by the translabyrinthine approach, and 5 had surgery by the retrosigmoid route. Six patients were ventilated overnight following surgery. All had histological confirmation of the diagnosis after an uneventful tumor excision. Ethical approval for the study was granted, and informed consent was obtained from all patients agreeing to take part.

Data Collection

A lumbar catheter (internal diameter 0.7 mm) was inserted the evening before surgery in 10 patients who had tumors less than 2.5 cm and no evidence of hydrocephalus. In the remaining cases, the catheter was inserted while the patient was in the surgical theater immediately after wound closure. All patients were given prophylactic antibiotics (flucloxacillin 250 mg every day) while the lumbar catheters were in place. CSF pressure was monitored continuously for 4 days, but no CSF was drained. Blood pressure was monitored by an in-

dwelling arterial catheter. TCD flow velocity was recorded from the middle cerebral artery (MCA) on a daily basis in 10 patients (3 tumors = 2.5 cm, 7 < 2.5 cm) to assess the contribution of hemodynamic changes to alterations in CSF pressure and intracranial compliance.

The lumbar and arterial catheters were connected to pressure transducers and the analog output was transmitted via an A/D converter to a laptop computer running a standard intracranial pressure (ICP) monitoring system.⁶ From each 1-minute time interval, the program calculated time trends of the following measurements: (1) mean CSF pressure; (2) amplitude of CSF pressure pulse wave (Amp) (calculated after careful filtering of noise and artifacts using spectral analysis); and (3) RAP (R-correlation between A-amplitude and P-pressure) coefficient, which is the Pearson correlation coefficient between amplitude of pulse wave and CSF mean pressure.

Data Analysis

Each day mean values for all the variables were calculated for each patient. Data from all the patients were then pooled to give mean values for each variable for each day. The overall significance of changes in the variables over the whole period of measurement was tested using a repeated measures analysis of variance. Differences between mean values for each day were tested using a paired *t* test with Bonferroni correction for multiple comparisons.

Wound Closure Technique

In the modified translabyrinthine wound closure technique, the incus is removed and a posterior tympanotomy slot is cut. This exposes the middle ear cavity and mesotympanic end of the eustachian tube, and these are packed with small pieces of fat. The bony posterior canal wall, the fat in the aditus, the vestibular side of the stapes footplate, and the facial nerve are then covered with a paste made of bone dust and autologous blood. A patch of fascia lata is cut to size, tucked around the fallopian canal and over the medial surface of the stapes footplate, and fixed in position over the bone paste with fibrin glue (Tisseel, Immuno AG, Vienna, Austria). The cavity in the temporal bone is obliterated with three 5-by 1-cm strips of fat whose tips are placed through the dural defect just abutting the cerebellopontine angle. The remaining fibrin glue is then used to anchor the fat superficially. The flap of pericranium that was raised from the mastoid bone at the start of the operation is replaced and sutured, and the remainder of the fascia lata is glued and sutured to the temporalis fascia over the suture line. The galea aponeurotica and skin are closed in separate layers.

In retrosigmoid wound closure, a laterally based dural flap is raised from the petrous face before the posterior meatal lip is drilled away. Any exposed air cells on the posterior lip are obliterated with fat fragments or bone paste. The dural flap is then replaced and reinforced with a fascia lata patch held in position on the meatal lip with fibrin glue. The posterior fossa dura is closed with a continuous suture and the remaining mastoid air cells are obliterated with bone paste. A patch of fascia lata is sealed over the exposed dura and mastoid air cells with fibrin glue and is held in place with a small strip of fat before closure of pericranium and skin.⁵

RESULTS

A typical pressure recording is shown in Figure 1. Gaps in the recording occurred during transfer of the patient between wards or when the lumbar catheter was kinked. Mean CSF pressure overnight prior to surgery was 11.4 mm Hg (SD 6.1) and rose to a maximum of 19.6 mm Hg (SD 5.2) on the first postoperative day ($p < 0.01$). All patients showed a rise in CSF pressure after surgery that rapidly settled over the following 3 days (Table 1, Fig. 2). This rise in pressure was associated with an increase in the amplitude of the CSF pressure pulse wave (Fig. 3) from 1.32 mm Hg (SD 0.86) to 3.84 mm Hg (SD 2.91) ($p < 0.02$) and an increase in the RAP coefficient (Fig. 4) from 0.57 (SD 0.25) to 0.83 (SD 0.11) ($p < 0.01$). There were no significant changes in

MCA blood flow velocity or in mean arterial blood pressure throughout the recording period (Table 1). The pattern of CSF pressure changes and the blood flow velocities in the 6 patients who were ventilated overnight following surgery were the same as those observed in the rest of the group.

There were a number of relevant complications. CSF pressure remained very high (more than 25 mm Hg) for 3 days after operation in a patient with a large tumor. Although the patient remained well throughout and a computed tomography (CT) scan showed no evidence of hydrocephalus, it was decided to reduce CSF pressure therapeutically. Another patient with preoperative and postoperative ventricular enlargement became confused 24 hours post surgery and had a ventriculoperitoneal shunt inserted. Both patients underwent therapeutic CSF drainage and have therefore been excluded from the analysis of the data. One of the monitored patients developed a CSF leak from the wound 9 days postoperatively, although CSF pressure had returned to normal within 4 days of surgery. The wound was reexplored and a bony defect was found in the posterior canal wall above the fascia lata graft. The leak appeared to result from a technical failure of wound closure rather than from excessive CSF pressure. Three patients developed pyrexia and headache on the 4th postoperative day. The lumbar catheters were removed and CSF specimens were sent for microscopy and culture. All three CSF specimens contained polymorphs, but no bacteria were seen or cultured. In each case the

Figure 1. Example of time trend of CSF pressure recorded before and after surgery. Gaps in the recording were caused by transfer of the patient between wards and unreliable pressure recording due to a kinked catheter.

Table 1. CSF pressure (CSF-P), Amplitude of CSF-P Pulse Wave (Amp), RAP Coefficient (RAP), MCA Flow Velocity (FV) and Gosling Pulsatility Index (PI) Values for Day Before Surgery (B), Night After Surgery (0), and Subsequent 4 Days (1–4). (Standard Deviation)

Days	CSF-P mm Hg	Amp mm Hg	RAP	FV (n = 10) cm/s	PI (n = 10)
B (n = 10)	11.4 (6.1)	1.32 (0.86)	0.57 (0.25)	56.3 (2.1)	0.85 (0.09)
0	13.9 (6.4)	2.31 (1.66)	0.61 (0.20)	53.4 (17.4)	0.97 (0.22)
1	19.6 (5.2)*	3.84 (2.91)*	0.83 (0.11)*	53.1 (17.6)	1.10 (0.28) [†]
2	12.1 (5.6)	2.74 (2.77)	0.70 (0.23)	63.0 (11.4)	0.97 (0.19)
3	6.7 (2.3)	2.3 (1.88)	0.46 (0.26)	56.0 (14.6)	1.02 (0.20)
4	3.5 (2.2)*	2.4 (1.43)	0.52 (0.17)	68.5 (13.4)	1.07 (0.33)

* $p < 0.01$, [†] $p < 0.05$ compared with value on day B (n = 30 unless otherwise specified)

pyrexia settled within 24 hours of removing the catheter.

DISCUSSION

Postoperative CSF Fistula

CSF fistula following surgical excision of acoustic neuroma remains a common and serious complication. King and Morrison⁷ operated on 150 patients by the translabyrinthine approach and reported an incidence of 14% rhinorrhea, 7% wound leakage, and 4% meningitis. Glasscock et al² reported 616 cases operated on using predominantly the translabyrinthine approach that had an overall leak rate of 14% and a meningitis rate of 5%. More recently, Kane et al⁸ reported a CSF leak rate of

15% in 61 patients operated on using the retrosigmoid approach exclusively. If postoperative leakage of CSF occurs, lumbar drainage of CSF leads to resolution in less than 50% of cases. Most patients require surgical repair of the fistula.¹

Using a modified wound closure technique and by performing daily lumbar punctures a dramatic reduction in postoperative CSF leaks to 1.6% has been achieved by the Cambridge Otoneurosurgical Service.⁵ However, daily lumbar punctures are uncomfortable for patients and time consuming for medical and nursing staff. Continuous drainage of CSF by lumbar catheter is associated with a risk of infection and meningitis. For these reasons, this study was undertaken to measure perioperative CSF pressure changes to help determine whether therapeutic CSF drainage is useful in the prevention of postoperative fistula.

Figure 2. Time distribution of the mean value of CSF pressure (n = 30 patients). The asterisk indicates a statistically significant difference ($p < 0.01$) between mean preoperative CSF pressure and CSF pressure on days 1 and 4.

Figure 3. Time distribution of the mean value of the amplitude of the CSF pressure pulse wave ($n = 30$ patients). The asterisk indicates a statistically significant difference ($p < 0.01$) between mean preoperative amplitude and the mean value for day 1.

Figure 4. Time distribution of the mean value of the RAP coefficient ($n = 30$ patients). The asterisk indicates a statistically significant difference ($p < 0.01$) between mean preoperative RAP value and RAP values calculated for days 1 and 4.

Postoperative ICP Monitoring

Monitoring of ICP in the postoperative period is routine in some units, but most of the published data from these patients refer to heterogeneous groups of patients mostly with supratentorial pathology.⁹ Beks et al¹⁰ studied 86 patients, and most had a rise in ICP from 0 to 5 mm Hg in the immediate postoperative period to a mean of 8 to 15 mm Hg that persisted through the rest of the 4-day monitoring period. In only 14 patients was there an increase in ICP above 35 mm Hg. Patients who had drainage of CSF during the operation reached plateau ICP more quickly than did those who had no drainage.

There are no data concerning the natural history of ICP changes following acoustic neuroma surgery, although direct monitoring of posterior fossa pressure following surgery has previously been undertaken. During surgery for a variety of posterior fossa mass lesions, Rosenwasser et al¹¹ placed a catheter in the cerebellopontine angle and a Richmond bolt in the frontal area. Continuous monitoring of supratentorial and infratentorial pressure was undertaken for 48 hours. In the early postoperative period supratentorial pressures failed to reflect the posterior fossa pressure, but after 48 hours of monitoring, the pressures had equilibrated. Most patients had a small rise in ICP between 24 and 48 hours. Poon¹² undertook simultaneous monitoring of supratentorial ventricular pressure and posterior fossa subdural pressure in 25 patients after surgery for a mass lesion in the posterior fossa. There was good correlation between supratentorial and infratentorial pressures except in patients with obstructive hydrocephalus. Only patients with space-occupying complications developed raised ICP in the postoperative period.

Craniospinal Compensatory Reserve

Although preoperative pressure data in the present study are limited because only patients with small tumors were monitored, the findings suggest that there is an increase in CSF pressure in the first 24 hours after surgery. This rise in pressure then declines over the next 72 hours to values below those measured preoperatively. These changes in CSF pressure are accompanied by changes in craniospinal compensatory reserve. There is a well-recognized relationship between intracranial volume and pressure.¹³ When the volume of all the intracranial components is within the normal range, increases in volume are well-compensated for and result in only small increments in ICP. When the intracranial volume exceeds this range, any further increases are poorly compensated for and can result in sudden and large increases in ICP. Estimation of craniospinal compensatory reserve is possible because, as the reserve falls, arterial pressure pulsations are more effectively transferred to CSF pressure waves. The

RAP value is given by the correlation coefficient between the mean CSF pressure and the amplitude of the CSF pressure pulse wave. RAP values close to +1 indicate poor compensatory reserve, and values close to 0 imply good pressure volume compensation. In states of moderate intracranial hypertension this coefficient may be used as an indicator of exhaustion of the compensatory reserve.^{14,15} The changes measured in CSF pressure and RAP must result from an increase in volume of one of the intracranial compartments and may be accounted for by an obstruction to CSF flow, cerebral vasodilatation, or cerebellar swelling.

CSF Flow Obstruction

During surgery a large amount of CSF is drained, but CSF is produced at a rate of 0.3 ml per minute, which results in a rapid replenishment of this compartment. If CSF absorption is impaired by blood and surgical debris blocking absorption through the arachnoid villi then CSF volume will increase, pressure will rise, and compensatory reserve fall. The rises in CSF pressure and RAP were rapidly reversed over the subsequent 3 days without therapeutic drainage of CSF. This implies that any deficiency in CSF absorption is only a transient phenomenon and that therapeutic CSF drainage is not necessary to reverse the postoperative abnormalities in CSF dynamics.

Although it cannot be said that CSF drainage is never required to restore normal CSF flow, it would appear to be unnecessary in most patients undergoing surgery to remove an acoustic neuroma. An important shortcoming of the experimental method is that insertion of a lumbar drain inevitably damages the dural sac and CSF can leak out during the study period. Although leakage was not observed by the nursing staff, it may have occurred occultly into soft tissues.

Cerebral Hemodynamics

The rise in CSF pressure and fall in compensatory reserve seen postoperatively may be accounted for by an increase in cerebral blood volume (CBV) secondary to cerebral vasodilatation. Vasodilatation may be a consequence of general anesthesia or may result from a nonspecific impairment of autoregulation following surgery. Although CBV was not measured directly, cerebral vasodilatation is normally accompanied by increased blood flow velocity (FV) in the basal arteries. No significant changes in flow velocity were recorded in the postoperative period but there was a significant increase in the Gosling pulsatility index. This index is given by

$$\frac{\text{Systolic FV} - \text{Diastolic FV}}{\text{Mean FV}}$$

An increase in the Gosling pulsatility index occurs when ICP is moderately elevated because diastolic flow velocity falls while systolic flow velocity remains stable. The TCD results did not indicate any significant cerebral vasodilatation, and therefore it is unlikely that the fall in compensatory reserve was caused by an increase in CBV. However, more direct measurements of CBV with positron emission tomography are required to exclude the possibility that changes in CBV may contribute to the observed changes in pressure and compliance.

Cerebellar Swelling

Any operation that involves prolonged retraction of the brain is likely to be accompanied by postoperative cerebral swelling. Cerebral tissue constitutes the third main intracranial volume compartment, and significant cerebellar swelling could account for both the transient rise in CSF pressure and the diminished compensatory reserve that occurred in this study. However, most operations were undertaken by the translabyrinthine approach, in which there is rarely any need for retraction of the cerebellar hemisphere. Therefore, it seems unlikely that postoperative swelling could account for the changes in CSF pressure and craniospinal compliance.

CONCLUSION

The results of this study demonstrate a transient uncompensated dynamic process affecting CSF pressure and craniospinal compliance that is provoked by surgery. The most plausible explanation for this disturbance is impaired CSF absorption that resolves rapidly in most patients without therapeutic CSF drainage. CSF pressure rises transiently for 48 hours, and lumbar puncture on the 1st and 2nd postoperative days can be justified during this period when CSF pressure is highest. Even though CSF pressure returns to normal, the strength of the wound may not be equivalent to that of normal tissue in the initial days after the surgery. A return to the normal range of CSF pressure may therefore not be sufficient to prevent CSF leakage. We believe that prevention of CSF fistula depends primarily on meticulous wound closure technique.

This study does not provide a definitive answer as to whether therapeutic CSF drainage reduces the risk of

postoperative wound leak. However, the observed changes in CSF pressure provide a rationale for early postoperative lumbar puncture to counter the transient rise in CSF pressure we have observed. Surgeons who do not perform postoperative lumbar puncture can be assured that the CSF pressure will rapidly return to normal in the vast majority of their patients.

REFERENCES

1. Mangham CA. Complications of translabyrinthine vs. suboccipital approach for acoustic tumor surgery. *Otolaryngol Head Neck Surg* 1988;99:396-400
2. Glasscock ME, Kveton JF, Jackson CG, Levine SC, McKennan KX. A systematic approach to the surgical management of acoustic neuroma. *Laryngoscope* 1986;96:1088-1094
3. House JL, Hitselberger WE, House WF. Wound closure and cerebrospinal fluid leak after translabyrinthine surgery. *Am J Otolaryngol* 1982;4:126-128
4. Hardy DG, Macfarlane R, Baguley D, Moffat DA. Surgery for acoustic neurinoma. An analysis of 100 translabyrinthine operations [see comments]. *J Neurosurg* 1989;71:799-804
5. Hardy DG, Macfarlane R, Moffat DA. Wound closure after acoustic neuroma surgery. *Br J Neurosurg* 1993;7:171-174
6. Czosnyka M, Wollk LP, Batorski L, Zaworski W. Analysis of intracranial pressure waveform during infusion test. *Acta Neurochir (Wien)* 1988;93:140-145
7. King TT, Morrison AW. Translabyrinthine and transtentorial removal of acoustic nerve tumors. Results in 150 cases. *J Neurosurg* 1980;52:210-216
8. Kane NM, Kazanas S, Maw AR, et al. Functional outcome in patients after excision of extracranial acoustic neuromas using the suboccipital approach. *Ann R Coll Surg Engl* 1995;77:210-216
9. Takagi H, Miyasaka Y, Morii S, Ohwada T, Yada K. Clinical experience of 780 cases of post-operative ICP monitoring. In: Miller JD, Teasdale GM, eds. *Intracranial Pressure 6*. Berlin: Springer-Verlag; 1986:695-700
10. Beks J, Journee H, Albarda S, Flandertj A. The significance of ICP-monitoring in the post-operative period. In: Beks J, Bosch D, Brock M, eds. *Intracranial Pressure 3*. Berlin: Springer-Verlag; 1976:251-255
11. Rosenwasser RH, Kleiner LI, Krzeminski JP, Buchheit WA. Intracranial pressure monitoring in the posterior fossa: a preliminary report [see comments]. *J Neurosurg* 1989;71:503-505
12. Poon W. Intracranial pressure monitoring in the posterior fossa. In: Nagoi H, Kamiya K, Ishi S, eds. *Intracranial Pressure 9*. Berlin: Springer-Verlag; 1994:452-453
13. Lofgren J, von Essen C, Zwetnow NN. The pressure-volume curve of the cerebrospinal fluid space in dogs. *Acta Neurol Scand* 1973;49:557-574
14. Czosnyka M, Price DJ, Williamson M. Monitoring of cerebrospinal dynamics using continuous analysis of intracranial pressure and cerebral perfusion pressure in head injury. *Acta Neurochir (Wien)* 1994;126:113-119
15. Czosnyka M, Whitehouse H, Smielewski P, Kirkpatrick P, Guazzo EP, Pickard JD. Computer supported multimodal bedside monitoring for neuro intensive care. *Int J Clin Monit Comput* 1994;11:223-232