Predictive value of preoperative ventricular volume on the need for permanent hydrocephalus treatment immediately after resection of posterior fossa medulloblastomas in children

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Object. In this study, the authors investigated whether preoperative ventricular volume can be used to predict the need for permanent treatment of hydrocephalus in children with posterior fossa medulloblastomas.

Methods. Ventricular volumes were measured on magnetic resonance imaging studies obtained preoperatively and immediately postoperatively in 20 children who had undergone resection for medulloblastomas between 1999 and 2007. Comparison of mean values was performed using the one-way analysis of variance test. The association between ventricular and tumor volume was also investigated.

Results. All patients had obstructive hydrocephalus preoperatively, and 4 patients required postoperative shunt placement. The mean preoperative ventricular volume was 252 ml for those who required shunt placement, and 106 ml for those who did not (p = 0.000). The postoperative ventricular volume was 157 and 78 ml, respectively (p = 0.039), larger than normal in both groups. The mean postoperative and preoperative ratios were 0.69 and 0.70, respectively (p = 0.932). There was no correlation of ventricular volumes with age at operation (older or younger than 3 years), presence of metastasis, or amount of residual tumor. There was a statistical correlation between the preoperative ventricular volume and the tumor volume, related to the need for permanent shunt placement.

Conclusions. Preoperative ventricular volume has predictive value for the later need for shunt placement, but in clinical practice this may be difficult to appreciate because all patients have significant hydrocephalus at presentation. The rate of ventricular size reduction in response to tumor excision does not have predictive value because ventricular volume is related to tumor volume. It appears that the removal of cerebellar medulloblastoma converts hydrocephalus from obstructive to communicating, which requires surgical treatment if it exceeds a certain level of cerebrospinal fluid volume. (DOI: 10.3171/PED/2008/1/6/451)

KEY WORDS • hydrocephalus • medulloblastoma • posterior fossa tumor • shunt • ventricular volume

MEDULLOBLASTOMAS constitute ~ 20% of childhood cerebral tumors,1,2,20,21,27 representing 33% of tumors of the posterior cranial fossa, and 40% of cerebellar tumors.2 The incidence of hydrocephalus in children with medulloblastoma at the time of presentation varies in different series between 82 and 91%.6,12,16,22 However, the rate of permanent shunt placement or ETV after resection for primary medulloblastoma is 22–63% in the literature.3,4,6,12,13,19 Some authors have claimed that performing an ETV prior to resection of posterior fossa tumors in children with associated hydrocephalus statistically reduces the incidence of postoperative hydrocephalus requiring permanent shunting from 27 to 6%.23 Despite this significant reduction, the routine use of ETV may also result in a significant proportion of patients undergoing an unnecessary procedure with the concomitant risk of complications.9,11,25,28 On the other hand, ventricular shunt insertion in such patients prior to medulloblastoma surgery may result in hemorrhage within the tumor, or upwards herniation,7,8,23 and it has been suggested that the patients who undergo CSF drainage procedures (either EVD or shunt placement) within 30 days of medulloblastoma resection may have a significantly shorter survival time than those who do not.4

In view of the lack of consensus concerning the best management of hydrocephalus before or after resection of medulloblastoma,23 we studied a series of cases of histologically proven medulloblastoma to establish whether pre-
operative ventricular volume can predict the need for permanent hydrocephalus treatment after resection, so that unnecessary and potentially risky CSF drainage operations can be avoided preoperatively.

**Clinical Materials and Methods**

All patients included in the present study are from the West Midlands region of the United Kingdom (population of ~5.2 million people and 1 million children), and have been followed up exclusively at our hospital since the date of diagnosis. Each child with a brain tumor is routinely registered with the Cancer Registry of our hospital and the CCLG Registry at the time of admission and diagnosis. All patients included in this study underwent surgical excision of a posterior fossa medulloblastoma between May 1999 and May 2007 performed by 1 of 5 neurosurgeons. Most patients had been recruited to CCLG clinical trials that were active at the time of presentation, and hence most information had been collected prospectively. Since the late 1990s, our protocol has been to perform immediate postoperative MR imaging of the brain within 48 hours of surgical excision to verify the extent of excision.

All patients included in this study met the following criteria: 1) they had a histologically proven posterior fossa medulloblastoma; 2) had not undergone a preoperative CSF drainage procedure; and 3) had pre- and postoperative (obtained within 48 hours) digital MR brain images for analysis.

Ventricular volume was measured using the segmentation technique on axial T2-weighted MR scans with 5-mm slice thickness and 1.5-mm intervals. For comparison, contrast-enhanced T1-weighted sequences were used to identify the extent of tumor resection. The segmentation technique involves both manual and semiautomatic outlining (Fig. 1), as discussed in earlier reports. The area of every outline was measured in each slice, and the volume was calculated by multiplying the area of the outline by the slice thickness. We have reported on accuracy and validation issues in measurements on MR images in other similar studies. Validation between T1- and T2-weighted MR images has shown no difference in the volumes calculated on the T2-weighted images, although there is the subjective impression that T2-weighted images overestimate the amount of CSF. The total volume in the 3 ventricles (the lateral ventricles and third ventricle) was calculated. The volume of the fourth ventricle was not measured because of compression or effacement by the tumor preoperatively and postoperative anatomical distortion, with the occasional presence of a pseudomeningocele, resulting in unreliable outlining.

The preoperative tumor volume in all patients had been calculated on T1-weighted, contrast-enhanced MR images for a separate study using the same segmentation technique as we used for ventricular volume calculation, hence tumor volumes were available for comparative analysis.

The sex, age at diagnosis, and the need for permanent surgical treatment of hydrocephalus after tumor excision were recorded. The ratio of postoperative/preoperative ventricular volume was calculated to assess the rate of ventricular change after resection. Commercially available software was used (SPSS version 12.0.1, SPSS, Inc.) for statistical analysis. Comparison of mean values was performed using the one-way ANOVA, and statistical significance was set at a probability value of 0.05. To determine whether there was a correlation between ventricular and tumor volumes with respect to the need for permanent shunt placement, the ventricular volumes were plotted against the tumor volumes to assess any clustering of values. The 2 volumes were subsequently multiplied by one another, and the mean values of the new variable (the product) was compared with one-way ANOVA with respect to the need of permanent shunting. Indications for postoperative shunt placement included intracranial hypertension symptoms in the setting of ventriculomegaly, or the presence of significant pseudomeningocele. Ventriculomegaly without intracranial hypertension was not considered an indication for shunting. Routine postoperative lumbar punctures have not been used to treat ventriculomegaly or pseudomeningocele.

**Results**

Twenty patients were included in the study—16 boys and 4 girls with a mean age of 80.2 months (range 29–152 months) at the time of surgery. Only 2 patients were younger than 3 years old. The postoperative follow-up period was 5–69 months (mean 28.6 months). Postoperatively, 4 patients (20%) required shunts. All 4 of these patients were older than 3 years at the time of the operation, and after an
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immediate recovery from the operation had a decreasing level of consciousness associated with ventriculomegaly a few days postoperatively. The time between tumor removal and shunt placement was 6–10 days. None of the patients who received shunts had infected CSF in microbiological cultures. There was no correlation between the need for permanent hydrocephalus treatment and age over/under 3 years at operation, the presence of metastatic disease, the duration of symptoms, the amount of residual tumor after resection (above or below 15% of the original tumor volume), and the preoperative or immediate postoperative tumor volume (p > 0.484, chi-square test). As part of a set oncological treatment protocol, the presence of metastatic disease was determined in all patients on preoperative spinal imaging and with postoperative lumbar puncture and CSF cytological cultures performed 15 days postoperatively.

For the whole group, the mean preoperative ventricular volume was 135 ml (range 60–374 ml), the mean postoperative volume was 93 ml (range 16–293 ml), and the mean postoperative/preoperative ventricular volume ratio was 0.70 (range 0.20–1.19), indicating a mean 30% postoperative reduction in ventricular volume. Table 1 summarizes the pre- and postoperative ventricular volumes in both groups of patients. The difference in mean pre- and postoperative ventricular volumes between the 2 groups was statistically significant (p = 0.000 and 0.039, respectively; one-way ANOVA), and in both groups the mean postoperative ventricular volumes were abnormally high. There was no statistical difference between the pre- and postoperative ventricular volumes and the volume ratio according to age at operation (p > 0.227, one-way ANOVA), the presence of metastatic disease (p > 0.175, one-way ANOVA), or the amount of residual tumor after resection (above or below 15% of the original tumor volume; p > 0.819, one-way ANOVA).

Figure 2 shows the distribution of preoperative ventricular volume versus patient age for the 2 subgroups. It is clear that there is little overlap between the patients who later required hydrocephalus treatment and those who did not.

We investigated the correlation between the preoperative ventricular and tumor volume. The mean tumor volume was 36.6 ml (range 16.6–57.7 ml, median 41.6 ml). The mean tumor volume in patients who required permanent shunt placement was 40.9 ml, and 35.5 ml in those who did not (p = 0.484, one-way ANOVA). A scatter plot of the distribution of ventricular volume versus the tumor volume for the 2 subgroups of patients is shown in Fig. 3. Three of the 4 patients who required shunts had tumor volumes larger than the mean value. The ventricular volumes in these 3 patients were also at the higher end of the volume range, indicating a correlation between preoperative tumor and ventricular volumes. This relationship was further examined by multiplying the 2 volumes. There was a statistical difference in the product of tumor and ventricular volumes (p = 0.010, one-way ANOVA) between patients who required shunts and those who did not, the former having larger values. This finding suggests that ventricular volume is related to tumor volume.

**Discussion**

Although there are many studies of the management of obstructive hydrocephalus in children with posterior fossa tumors, there is no consensus as to the way hydrocephalus should be managed.1,6,10,13,14,16,17,22–24 The ventricular index has been used as a tool for assessing the degree of preoperative obstructive hydrocephalus secondary to posterior fossa tumors, but there is no agreement among authors concerning its validity as a predictor of the need for shunt placement.3,14,17,24

Apart from the extent of preoperative hydrocephalus, Culley et al.1 studied many other factors possibly related to the need for ventricular shunt placement after posterior fossa tumor surgery in children, including age at diagnosis, duration of symptoms, tumor location, extent of tumor resection, presence and duration of EVD in situ, flow of CSF through the fourth ventricle after tumor resection, presence of hemostatic cavity linings, method of dural closure, tumor type, the presence of CSF infection, CSF leakage, and pseudomeningocele formation. Of these variables, these authors found that age younger than 3 years at diagnosis, tumors
years of age, which may explain the lack of correlation found between age and the need for shunt placement, which is contrary to what has been described in the literature previously. Of interest is the association between ventricular and tumor volumes, indicating that large ventricles are caused by the longer-term presence of obstructive hydrocephalus, assuming that it takes longer for the tumor to grow to a larger size given the same level of malignancy. On the other hand, there was no correlation between the need for permanent shunting and symptom duration, another indirect sign of the rapidity of tumor growth.

The present study should be considered a pilot work offering a potential guideline for the need for shunt placement rather than a definitive work on the topic. A possible way forward would be to extend it to a multicenter study with larger numbers of patients. At the very least, validation of these results should be pursued with data from another independent institution.

The results of this study demonstrate that after tumor excision, the ventricular volume is reduced by an average of 30% in the first 2 days, regardless of whether the child requires a shunt or not. All children had higher than normal ventricular volumes, implying that they all had communicating hydrocephalus immediately postoperatively. A similar observation was made in another study from our group. After ETV for obstructive hydrocephalus, the ventricular volume was reduced by 40% at the end of the first postoperative week. Even with this reduction, the volume was still higher than normal, and remained higher than normal in the long-term. There is the impression that a threshold of supranormal CSF volume exists, above which the clinical picture of hydrocephalus develops (ventriculomegaly with raised CSF pressure) and which requires surgical treatment because it does not resolve spontaneously. This observation is in broad agreement with the work of Nishiyama et al., who showed that CSF dynamics convert from a shunt-dependent state to a shunt-independent state within 1 week after ETV in patients with shunt-dependent noncommunicating hydrocephalus. Nonetheless, intraventricular pressure does not decrease quickly in certain cases, and CSF absorptive capacity or CSF circulation through the subarachnoid space may improve further several months after ETV.

It would be beneficial for the patient with preoperative hydrocephalus secondary to a posterior fossa tumor if the neurosurgeon could predict the possibility of postoperative hydrocephalus requiring a CSF diversion procedure. In these cases, ETV could be considered prior to tumor resection, and postoperative EVD or shunt insertion could be avoided. The present study cannot be used as an absolute guideline, but our results strongly suggest that patients with very large ventricles and possibly very large tumors are more likely to need permanent hydrocephalus treatment postoperatively.

Conclusions

Preoperative ventricular volume has predictive value for the later need for shunt placement in children who present with posterior fossa medulloblastomas. However, in clinical practice it may be difficult to appreciate this, as all patients have significant hydrocephalus at presentation. The rate of ventricular size reduction in response to tumor excision does not have predictive value. It appears that removal
of medulloblastomas obstructing the fourth ventricle converts hydrocephalus from obstructive to communicating, which requires surgical treatment if the CSF volume exceeds a certain level.

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