Mutism and Pseudobulbar Symptoms after Resection of Posterior Fossa Tumors in Children: Incidence and Pathophysiology

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MUTISM AND A variety of other neurobehavioral symptoms have been reported anecdotally after the removal of posterior fossa mass lesions. To determine the incidence and clinical spectrum of this syndrome, a detailed review was performed of patients undergoing resection of infratentorial tumors at our institution during the last 9 years; 12 of 142 patients (8.5%) manifested this syndrome, the largest series of such patients reported to date. Each child had a lesion that involved the vermis; seven had medulloblastomas, three had astrocytomas, and two had ependymomas. The incidence among children with vermian neoplasms was 13%. Ten children underwent division of the inferior vermis during tumor resection, and three had a superior vermian incision; one child underwent both superior and inferior vermian incisions. In 10 children, mutism developed in a delayed fashion postoperatively. The speech disturbance was associated with poor oral intake in 9 children, urinary retention in 5, long-tract signs in 6, and bizarre personality changes, emotional lability, and/or decreased initiation of voluntary movements in all 12. Neuropsychiatric testing, performed in seven children, confirmed impairments not only in speech but also in initiation of other motor activities. Ten children regained normal speech, bladder control, and neurological functioning, other than ataxia and mild dysarthria, within 1 to 16 weeks; two children had significant residual deficits. Characteristically, affect and oral intake returned to their preoperative baseline before the speech difficulties began to resolve. A detailed radiological review of these cases in parallel with 24 cases of vermian tumors without mutism identified only one factor that was significantly associated with the mutism syndrome, bilateral edema within the brachium pontis ($P < 0.01$). Neither the size of the tumor nor the length of vermian incision was associated with the development of mutism. The clinical features of this syndrome in the context of these imaging findings suggest that the mutism syndrome results from transient impairment of the afferent and/or efferent pathways of the dendate nuclei that are involved in initiating complex volitional movements. The clinical courses of our patients are presented and compared with those of similar cases in the literature in an attempt to evaluate the validity of this hypothesis. (Neurosurgery 37:885–893, 1995)

Key words: Cerebellum, Mutism, Posterior fossa tumor, Pseudobulbar syndrome, Vermis

The development of mutism and associated neuropsychiatric symptoms after resection of large vermian tumors was initially noted by Hirsch et al. (21) and Sakai et al. (32). Subsequently, a series of reports during the last decade have added to the delineation of this syndrome (3, 5, 6, 9–13, 17, 20, 23, 27, 31, 33, 35, 37, 38). In general, affected patients are children with large midline vermian lesions for whom the operation for tumor resection includes an incision of the inferior vermis. Because previous reports have described such cases anecdotally, it has been difficult to determine the frequency of this syndrome among patients with posterior fossa tumors. Moreover, because previous series have generally emphasized particular aspects of this syndrome, such as mutism, impaired eye opening, or pseudobulbar symptomatol-

ogy, the overall profile of this clinical syndrome has remained problematic.

In an attempt to more completely define the frequency and clinical characteristics of this syndrome, we reviewed the records of children who underwent resection of posterior fossa mass lesions at our institution during the last decade; 12 children with a combination of mutism and neurobehavioral symptoms were identified. Because these cases generally provoked both curiosity and consternation regarding the underlying causes of the deficits as well as their reversibility, a combination of detailed neuroimaging studies and neuropsychiatric testing was performed on many of the children to try to define the cause for this syndrome. The clinical courses of these patients are reported, along with the results of the evaluations, and these observations are critically examined in the context of the previously described cases of this syndrome in an attempt to elucidate the pathophysiological basis for this symptom complex.

PATIENTS AND METHODS

Patient population

The patient population included in this study was obtained by a detailed review of the Tumor Registry Data Bank, Neuro-oncology Clinic records, and operative records of children with posterior fossa mass lesions who were treated between 1985 and 1994 at the Children's Hospital of Pittsburgh. One hundred and forty-two patients who underwent open resection of an infratentorial tumor were identified, of whom 92 had lesions that primarily involved the vermis. The records of all patients with evidence of the aforementioned syndrome were reviewed in detail, and long-term follow-up data were obtained. Information was collected on the location of the lesion, the operation performed, the clinical course of symptom onset and progression, the presence or absence of other neurological findings or behavioral changes, the diagnostic evaluation performed, and the time course during which the symptoms resolved. Patients who exhibited neurobehavioral impairment in association with bacterial meningitis and those with profound neurological impairment as a result of either the tumor or the surgical procedure were excluded from the study group.

Radiological evaluation

To determine whether these patients had any distinguishing characteristics with regard to the appearance of the tumor preoperatively or the peritumoral brain postoperatively, computed tomography (CT) and magnetic resonance imaging (MRI) studies were reviewed in a blinded fashion by two neuroradiologists who were unaware of the patient's history. For each affected child, two age-matched patients with posterior fossa tumors who did not develop mutism were reviewed in parallel. In all patients, postoperative studies were obtained within 48 hours of operation. The images were graded on a variety of criteria, including lesion location and size and involvement of cerebellum, cerebellar peduncles, and brain stem by tumor or edema preoperatively and by edema or hemorrhage postoperatively. In addition, the extent of the cerebellar incision was determined. Late follow-up studies were also examined for areas of permanent injury. Parametric variables were examined for significance using Student's t test. Nonparametric variables were examined using a Fisher's exact test or a χ^2 test with Yates' correction.

RESULTS

General features of the affected patients

Twelve children in this series manifested a syndrome of postoperative mutism. As noted below, the spectrum of the syndrome in terms of the severity of the associated manifestations, such as pseudobulbar and neurobehavioral symptoms, and the duration of the speech impairment varied considerably among these children. Each of the patients had a lesion that involved the cerebellar vermis (in nine patients arising from the inferior vermis, in two patients from the superior vermis, and in one patient, with multiple metastatic nodules, affecting both areas). The incidence of this syndrome was 8.5% among the 142 children undergoing resection of posterior fossa mass lesions and 13.0% among the 92 treated for vermian lesions. Seven of the affected patients had a medulloblastoma, three had an astrocytoma, and two had an ependymoma. The patients ranged in age from 3.5 to 16 years; four were girls and eight were boys. All had normal speech preoperatively.

Each of these children had undergone placement of a coronal external ventricular drain as an initial step in the operation. A suboccipital craniotomy or craniectomy was then performed with the patient in the prone position. In each case, a portion of the vermis was split vertically to facilitate tumor removal. The procedures were all performed with monitoring of somatosensory evoked potentials and brain stem auditory evoked potentials; in no case were significant or lasting abnormalities detected intraoperatively. Continuous VIth and VIIth nerve electromyography was performed intraoperatively on Patients 4 through 12.

Eleven of these children underwent resections that were judged to be complete or nearly complete by the operating surgeon and the postoperative images. A ventriculostomy was left in place in the immediate postoperative period until it was apparent that the patient's cerebrospinal fluid was being adequately absorbed internally without intracranial pressure elevations. Two children required permanent cerebrospinal fluid diversion because of persistent dependence on the ventriculostomy for spinal fluid drainage. For all patients, the ventricular dilatation was much improved postoperatively as compared with the preoperative state.

Time course of mutism and associated impairments

The clinical characteristics of these 12 children are summarized in *Table 1*, which also includes a summary of previously reported cases of this syndrome. Each of these patients awoke uneventfully after the tumor resection, with the expected amounts of ataxia and dysmetria. Several had associated VIth and/or VIIth nerve paresis. Ten of 12 had normal vocalization

ability initially; several were witnessed to speak a few words or short phrases, whereas others were clearly communicating in sentences. Each of these patients then developed mutism within 24 to 96 hours. Two other patients failed to speak upon awakening from anesthesia but otherwise seemed alert.

The mutism generally did not occur as an isolated finding. All of these patients also manifested marked neurobehavioral abnormalities. Eleven children exhibited an almost stereotypical response, remaining curled up in bed and whining inconsolably, without actually uttering intelligible speech. Three exhibited prolonged periods of eye closure and seemed unable to initiate spontaneous eye opening. Five patients had urinary retention or incontinence without any clear urological or pharmacological basis. Nine patients also had significant impairment in oromotor coordination and seemed unwilling to eat; only two of these children had impaired gag reflex or abnormal pharyngoesophageal motility as evidenced by barium swallow studies. The other seven patients had no clear explanation for the eating impairment. These children appeared to have difficulty initiating the chewing and swallowing process; however, once the food was swallowed, there was no evidence of nasopharyngeal regurgitation or aspiration to suggest neurogenic dysphagia. Six patients had associated long-tract signs.

Each of these patients underwent a series of diagnostic studies to determine whether there was a structural basis for the symptoms. This included postoperative CT in eight patients and MRI in eight, which failed to show either significant hemorrhage in the resection bed, worsening hydrocephalus, or significant abnormalities elsewhere within the brain. Only one of these patients had radiographically detectable residual tumor. Three children underwent xenon computed tomographic cerebral blood flow studies, which failed to show focal areas of hypoperfusion. Single photon emission tomography with both ^{99m}Tc-HMPAO and ^{201}Th and positron emission tomography with 18-fluorodeoxyglucose in one patient each were also unremarkable.

The time course of clinical improvement varied significantly among patients. Ten were enrolled in a comprehensive program of speech therapy while hospitalized. Eight patients were maintained in intensive outpatient rehabilitation. In general, affect, oral intake, and urinary function returned to their preoperative baselines before the speech difficulties began to resolve. Five children began uttering single words within 2 weeks of surgery. The other seven children began to speak within 2 months of surgery. All patients recovered fluent speech within 4 months of surgery. In general, the character of the speech was profoundly abnormal during the recovery phase. Three of the children began speaking in a whispered voice and four others spoke in a high-pitched "whiny" voice. In all 12 children, the speech exhibited a dysarthric quality before fully recovering. One child was left with mild residual dysarthria.

Detailed neuropsychiatric testing was performed for seven of these children during the recovery phase and demonstrated impairment not only in speech but also in initiation and completion of age-appropriate motor activities. Several children also had impairments in recent memory, attention span, and problem-solving ability. The difficulties with cognition and initiation of activities ultimately cleared in each of these patients. Although several of the children have residual ataxia or dysmetria, all but two patients have been able to resume a full range of normal activities. Each of these children is currently alive without obvious disease, although one child with a large vermian astrocytoma that invaded the brain stem required subsequent operation for a focal area of progressive tumor within the middle cerebellar peduncle and brain stem.

Radiological findings in children with mutism versus those without

A blinded comparison of several features among the 12 patients with mutism and 24 without this syndrome identified no single feature that was pathognomic for the presence of postoperative mutism. Because each patient selected for the control group also had a vermian lesion, as did the 12 with mutism, tumor location was not a significant factor that distinguished the two groups. Maximum lesion diameter in the children with mutism (4.4 ± 1.1 cm) did not differ significantly from that of children without mutism (4.6 ± 1.6 cm). Preoperatively, hydrocephalus was present in 21 of 24 patients without mutism versus 10 of 12 with mutism.

On postoperative images, unilateral edema within the brachium pontis and/or brachium conjunctivum (i.e., low density on computed tomographic scans or high-signal intensity on T2-weighted magnetic resonance images) was seen in 11 of 12 patients with mutism versus 17 of 24 patients without ($P > 0.1$, χ^2 test). Bilateral edema within these structures was present in 9 of 12 patients with mutism versus only 6 of 24 controls ($P < 0.01$). Edema within the brain stem was seen in four patients with mutism versus two controls ($P > 0.1$). The rostrocaudal length of the cerebellar vermis incision in the patients with mutism (2.9 ± 1.2 cm) did not differ significantly from that of the patients without mutism (3.4 ± 1.0 cm). A review of the late follow-up MRI studies in each child demonstrated no focal areas of infarction, although several patients in both the mutism and control groups who had received posterior fossa radiotherapy exhibited volume loss within the cerebellum in association with persistent dilatation of the fourth ventricle.

ILLUSTRATIVE CASES

Patient 1

A 6-year-old girl presented with a 6-week history of morning vomiting and headache. CT demonstrated a 4-cm vermian tumor, which had produced moderate obstructive hydrocephalus. The lesion was completely resected via an incision in the inferior third of the vermis; the tumor invaded the fourth ventricular floor in the region of the right lateral recess. A histopathological examination disclosed medulloblastoma. The patient awoke from anesthesia without focal deficits and was reported to have spoken several words but, on the 1st postoperative day, developed mutism. She also manifested emotional lability, right-sided ataxia and tonic posturing, a right head tilt, limited spontaneous initiation of movements, and urinary retention. CT disclosed mild edema around the resection cavity and within the cerebellar peduncles bilaterally but no mass effect. The patient's affect

TABLE 1. Summary of Children with Mutism and/or Pseudobulbar Symptoms after Resection of Posterior Fossa Tumors[a]

Series (Ref. No.)	Age (yr), Sex	Tumor Site	Brain Stem Invasion	Histology	Postop Interval until Onset of Syndrome	Speech Impairment	Neurobehavioral Symptoms	Poor Oral Intake	Other Symptoms	Time until Beginning/ Completion of Speech Recovery	Residual Deficits
Wisoff and Epstein, 1984 (38)	6, M	Vermis	No	Malignant astrocytoma	24 h	Mutism	No	?	Bilateral VIIth CN palsy	2 wk/4 mo	AVM dysmetria
	12, M	Vermis	L lateral recess of 4th ventricle	Medulloblastoma	48 h	Mutism	Stupor	?	L Vth, IX–XIIth CN paresis, quadriparesis	2.5 wk/18 mo	L ataxia
	13, M	Vermis	No	Medulloblastoma	72 h[b]	Severe dysarthria	Emotional lability	Presumed	Vth and VIIth CN impairment, dysarthria, L hemiparesis	Several wk/6 mo	None
	3.5, M	Vermis	No	Medulloblastoma	72 h	Dysarthria	Emotional lability	?	Bilat VIIth CN palsy, quadriparesis	Gradual	Ataxia, dysarthria
	3.5, M	Vermis	No	Medulloblastoma	72–96 h	Mutism	Emotional lability	?	Bilat VIth CN palsy, ataxia	10 d/? wk	None
	17, M	Vermis	L lateral recess of 4th ventricle	Astrocytoma	48 h	Mutism	Emotional lability	?	R IVth CN palsy, facial paresis	Several wk/6 mo	None
Rekate et al., 1985 (31)	8, F	Vermis	?	Medulloblastoma	Immediate[b]	Mutism	No	4 d	R hemiparesis	6 wk/3 mo	Dysarthria
	6, M	Vermis	?	Astrocytoma	96 h	Mutism	Withdrawn, "whined"	?	None	3 wk/6 mo	None
	2, –	Vermis	?	Ependymoma	?	Mutism	?	?	None	1–3 mo/?	?
	10, –	Vermis	?	Medulloblastoma	?	Mutism	?	?	None	1–3 mo/?	?
	9, –	Vermis	?	Medulloblastoma	?	Mutism	?	?	None	1–3 mo/?	?
	11, –	Vermis	?	Medulloblastoma	?	Mutism	?	?	None	1–3 mo/?	?
Yonemasu, 1985 (39)	4 children	Vermis	?	2 medulloblastoma, 2 ependymoma	18–72 h	All had mutism	?	?	Ataxia	3–12 wk	?
Volcan et al., 1986 (37)	8, F	Vermis	No	Medulloblastoma	<24 h	Mutism	Cried in a shrill, whiny voice	?	R hemiparesis	2 wk/1 mo	Dysarthria
Humphreys, 1989 (23)	7, M	Vermis	Floor of 4th ventricle	Medulloblastoma	24 h	Mutism	Lay curled up in bed, eyes closed, poor recent memory	Yes	L arm weakness	4 mo/6 mo	None
	3, M	4th vent	L lateral wall of 4th ventricle	Medulloblastoma	Immediate	Mutism	Fussy, apathetic	No	None	7 wk/?	Yes[c]
	7, M	Vermis	Both lateral walls and floor of 4th ventricle	Medulloblastoma	Immediate	Mutism	Irritable, reluctant to move	Yes	None	2.5 mo/7 mo	None
	4.5, M	Vermis	Floor and lateral wall of R 4th ventricle	Fibrillary astrocytoma	72 h	Mutism	No	No	R arm weakness, L VIth CN paresis	7 wk/7 mo	R ataxia
	10, F	4th vent	Lateral wall of 4th ventricle; roof of aqueduct	Ependymoma	12 h	Mutism	Eyes closed	?	Gaze paresis, non-purposeful limb movements	10 wk/?	?
Ammirati et al., 1989 (5)	14, M	Vermis	?	Pilocytic astrocytoma	48 h	Mutism	?	?	?	6 wk/2 mo	?
Ferrante et al., 1990 (14)	9, F	Vermis	R lateral recess of 4th ventricle	Pilocytic astrocytoma	48–72 h	Mutism	No	Yes	No	1 mo/2 mo	None
	5.5, F	Vermis	R lateral recess of 4th ventricle	Pilocytic astrocytoma	48–72 h	Mutism	No	Yes	Ataxia	2 mo/6 mo	None
	6, M	Vermis	R lateral recess of 4th ventricle	Pilocytic astrocytoma	48 h	Mutism	No	Yes	Ataxia	1 mo/6 mo	Ataxia
Dietze and Mickle, 1990 (13)	7, M	Vermis	Attached to floor of 4th ventricle	Medulloblastoma	Immediate	Mutism	No	No	Ataxia	6 wk/3 mo	None
	15, F	Superior vermis	None	Arteriovenous malformation	Preoperative	Mutism	No	?	Ataxia	?/3 mo	Ataxia, dysarthria
Gaskill and Marlin, 1991 (17)	8, F	Vermis	R lateral wall of 4th ventricle	Medulloblastoma	?	Mutism	Eyes closed	No	Ataxia	2 wk/6 wk	Ataxia
Nagatani et al., 1991 (27)	4, F	Vermis	No	Medulloblastoma	24 h	Mutism	No	Yes	No	78 d/4 mo	None
Salvati et al., 1991 (33)	20, M	Vermis	No	Medulloblastoma	46 h	Mutism	No	No	Dysmetria	4 wk/7 wk	Dysmetria, dysarthria
Aguiar et al., 1993 (3)	2 children	Vermis	Unknown	Medulloblastoma	?	Mutism	No	No	?	?	?
Crutchfield et al., 1994 (10a)	7, M	Vermis	Unknown	Medulloblastoma	24–48 h	Mutism	No	No	Ataxia, dysmetria	7 wk/9 wk	Dysnomia
Cochrane et al., 1994 (10)	6 children	Not stated	Not stated	4 astrocytoma, 2 medulloblastoma	4 immediate, 2 delayed: 16 h and 7 d	All had mutism	All had emotional lability	?	Bulbar and cerebellar dysfunction	?/within 6 mo	Dysarthria

Daily and Berger, 1994 (11)	8 children (3–20, 5F/3M)	Vermis	Not stated	5 medulloblastoma, 2 astrocytoma, 1 ependymoma	Not stated	All had mutism	Not stated	All had difficulty swallowing	No lower CN deficits	1–12 wk/?	Not stated
Van Dongen et al., 1994 (35)	6, M	Vermis	Not stated	Medulloblastoma	24 h	Mutism	Apathetic with continuous whining	Yes	R hemiparesis, severe ataxia, eye deviation	5 wk/8 wk	None
	8, F	Vermis	4th ventricular floor	Medulloblastoma	48 h[b]	Mutism	Apathetic with soft whining	Yes	L VIth and VIIth paresis, tetraparesis	5 wk/12 wk	Died 6 mo postop of metastases
	8, M	Vermis	4th ventricular floor	Medulloblastoma	24 h	Mutism	Uncooperative	No	R arm paresis, limb ataxia	8 wk/12 wk	Ataxia
	5, M	Vermis	4th ventricular floor	Medulloblastoma	<24 h	Mutism	Apathetic, cried in a soft whining voice	No	Severe ataxia	8 wk/4 mo	Not stated
	4, M	Vermis	4th ventricular floor, R lateral recess, inferior colliculus	Ependymoma	24 h	Mutism	Apathetic, whined and cried	Not stated	R VIIth paresis, severe paresis and R ataxia	3 wk/4 wk	Ataxia
This study	6, F	Vermis	4th ventricle floor and R lateral recess	Medulloblastoma	18–24 h	Mutism	Emotional lability, limited initiation of activities, poor short-term memory	No	R ataxia and tonic posturing, urinary retention	6 wk/4 mo	R ataxia, dysmetria
	11, F	Vermis	L lateral recess of 4th ventricle	Ependymoma	24 h	Mutism	Lay curled up in bed, eyes closed, whined, refused to follow commands	Yes	L VIth and VIIth CN paresis, urinary retention	2 wk/2 mo	L VIth nerve paresis
	9, M	Vermis	No	Medulloblastoma	24 h	Mutism	Emotional lability, limited initiation of activities, poor short-term memory	No	Ataxia	7 d/4 wk	None
	10, M	Vermis	4th ventricle floor	Medulloblastoma	Immediate	Mutism	Emotional lability, refused to initiate activities	Yes	L VIth and VIIth CN paresis, ataxia	3 wk/6 mo	Ataxia, swallowing difficulties
	16, M	Vermis	No	Pilocytic astrocytoma	48 h	Mutism	Lay curled up in bed, eyes closed, whined, refused to follow commands, poor problem solving and memory	Yes	L hemiparesis, urinary retention	1 mo/3 mo	L ataxia
	9, M	Vermis	4th ventricle floor	Medulloblastoma	<24 h	Mutism	Refused to initiate activities, difficulty with problem solving	Yes	L ataxia, neglect	4 wk/4 mo	L ataxia, dysmetria
	6, F	Vermis	L middle cerebellar peduncle	Pilocytic astrocytoma	72–96 h	Mutism	Lay curled up in bed, eyes closed, whined	Yes	Ataxia, VIth CN paresis	10 d/3 wk	L ataxia
	9, M	Vermis	Both middle cerebellar peduncles, R 4th ventricle floor	Ependymoma	48–72 h	Mutism	Lay curled up in bed, whined, emotional lability	Yes	L ataxia, VIth CN paresis, urinary retention	10 d/2 mo	None
	8, F	Vermis	L 4th ventricle floor, middle cerebellar peduncle	Medulloblastoma	48–72 h	Mutism	Refused to initiate activities	Yes	Ataxia, L VIth and VIIth CN paresis	7 d/3 wk	None
	5, M	Vermis	R floor of 4th ventricle	Medulloblastoma	72 h	Mutism	Lay curled up in bed, whined	Yes	R hemiparesis, upgaze paresis, ataxia, urinary retention	14 d/6 wk	Ataxia, mild dysarthria
	3.5, M	Vermis	Lateral superior floor of 4th ventricle; R middle cerebellar peduncle	Astrocytoma	72 h	Mutism	Lay curled up in bed, whined	No	R ataxia, L hemiparesis	14 d/2 mo	Ataxia
	4, M	Vermis with mets to both cerebellar hemispheres	4th ventricle floor	Medulloblastoma	72 h	Mutism	Lay curled up in bed, whined	Yes	L arm ataxia, INO	18 d/4 wk	Ataxia

[a] 4th vent, fourth ventricle; ?, unknown; L, left; R, right; Postop, postoperative; CN, cranial nerve; Bilat, bilateral; INO, internuclear ophthalmoplegia; AVM, arteriovenous malformation.
[b] The patient developed initial symptoms after a second operation to remove a hematoma in the tumor resection cavity.
[c] The patient had residual deficits from a postoperative cerebral hemorrhage and chronic subdural hematoma.

brightened, and her urinary retention resolved 3 weeks after operation. Neuropsychiatric testing revealed that she had limited spontaneous initiation of either speech or movement. Her speech began to recover by the end of the 6th postoperative week but was whispered and monosyllabic. By the end of the 2nd postoperative month, her speech was more fluent but was still reported as being whispered and slow. By her 4-month follow-up visit, she had returned to her preoperative baseline, other than exhibiting mild right ataxia and dysmetria. She completed craniospinal radiotherapy and is presently disease-free 115 months postoperatively.

Patient 5

A 16-year-old boy presented with a 6-week history of headaches and left dysmetria. CT and MRI showed a hypodense, uniformly enhancing 4-cm superior vermian tumor causing mild obstructive hydrocephalus. The tumor was exposed via an incision in the upper one-third of the vermis and was completely resected. The tumor did not violate the fourth ventricular floor. A histopathological examination showed juvenile pilocytic astrocytoma. The patient awoke from anesthesia with no neurological deficits and clear speech but, by the 3rd postoperative day, had developed left hemiparesis, mutism, and a bizarre, depressed affect. He lay curled up in bed with his eyes closed, whining intermittently, refusing to follow commands, with poor oral intake and urinary retention. His speech consisted only of occasional expletives, which were uttered in a high-pitched nasal voice when the patient was asked to initiate movements. CT and MRI showed edema around the resection cavity, within the brachium pontis and brachium conjunctivum bilaterally, and within the rostral pons. A xenon computed tomographic/cerebral blood flow study revealed no abnormalities. The patient's poor oral intake and bizarre personality changes each improved by the the 3rd postoperative week; his urinary retention resolved shortly thereafter. He underwent serial neuropsychiatric testing during his recovery phase, which initially demonstrated poor initiation and completion of age-appropriate motor and problem-solving activities, despite improvement in his overall mood. These deficits improved gradually during a period of several months. During that time, his speech improved through a stage of dysarthria to its preoperative baseline. He returned to regular school classes by 3 months postoperatively; his only persistent deficit was mild left ataxia. No adjuvant therapy was administered. He is presently progression-free 58 months postoperatively.

Patient 8

A 9-year-old boy presented with several weeks of headache, meningismus, lethargy, and ataxia. During the week before admission, he became increasingly ataxic, developed a left head tilt, and experienced diplopia secondary to a left VIth nerve palsy. CT and MRI showed a partially calcified 5-cm vermian tumor, which was producing moderate obstructive hydrocephalus. The tumor had invaded both middle cerebellar peduncles and a punctate area of the right fourth ventricular floor but was completely resected; the inferior one-third of the vermis was divided during the resection. A histopathological examination demonstrated ependymoma. The patient was neurologically intact during the 1st postoperative day, except for mild left-sided ataxia and a left VIth nerve paresis. However, by the 3rd postoperative day, the patient had become completely mute. CT and MRI showed only mild edema around the resection cavity and the brachium pontis bilaterally. A single photon emission computed tomography scan with both ^{99m}Tc-HMPAO and ^{201}Th was completely normal.

Initially, the patient lay curled up in bed, whining and refusing to eat. He exhibited periods of extreme emotional lability. He also had urinary retention. By the 7th postoperative day, his urinary retention had resolved, his affect became cheerful, and his appetite returned to normal. Although he followed complex commands without difficulty, could write intelligible sentences, and had intact memory function, he remained mute until postoperative Day 10. At that time, a speech therapy consultant evaluated the patient and initiated a program of intensive treatment. His speech returned completely during the ensuing 6 weeks; however, he progressed initially through a phase of dysarthric speech and then a period of talking in a high-pitched "infantile" voice that he could volitionally suppress to speak in his "normal" voice. At 6-month follow-up, he had normal speech and no residual neurological deficits. He was treated with hyperfractionated local radiotherapy and adjuvant chemotherapy and is currently progression-free 24 months postoperatively.

DISCUSSION

During the last decade, more than 40 cases of mutism and/or bizarre personality changes have been reported after the removal of posterior fossa mass lesions. These are summarized in *Table 1*. As with our own patients, these patients have generally (but not exclusively [12, 33]) been young and have had large midline cerebellar and fourth ventricular tumors that were resected via an inferior vermian incision. Our Patients 5 and 11 and the second case of Dietze and Mickle (13) are distinctive in that a superior vermian incision was employed and the inferior vermis was not traversed. In the majority of cases, symptoms developed after an interval of relatively normal functioning in the immediate postoperative period and the deficits were largely reversible during the first few weeks to months after surgery. Although mutism is the central element in this syndrome, the majority of patients in our series and in several previous reports (10, 11, 17, 23, 31, 35, 37, 38) have had associated neurological and behavioral abnormalities that included a combination of emotional lability, poor oral intake, decreased spontaneous initiation of movements, impaired eye opening, and urinary retention. The incidence of this syndrome in this series (12 of 142 patients with posterior fossa tumors [8.5%]) was similar to the incidence reported by Cochrane et al. (10) (6 of 105 patients [5.7%]).

The causes and anatomic basis for this syndrome in children with posterior fossa tumors have remained conjectural. The cerebellum has long been known to play an important role in controlling speech (22), but the characteristic speech impairment that has been ascribed to cerebellar lesions is dysarthria rather than mutism. Dysarthria may result from unilateral lesions to a variety of sites within cerebellar hemispheres or deep nuclei (1, 25). That mutism occurs almost exclusively with midline cerebellar mass lesions that have been resected via an inferior vermian incision, but not with large cerebellar hemispheric tumors that have been resected without splitting the vermis, has been offered as presumptive evidence that bilateral injury to the inferior vermian region is a crucial element in the pathophysiology of this disorder. However, several factors indicate that the anatomic substrate for the overall syndrome of mutism and neurobehavioral changes is not within the inferior vermis but instead is localized to adjacent structures. First, if the caudal cerebellum did indeed house an area crucial for the initiation of speech,

deficits should not only be more common but also more persistent after resection of midline cerebellar tumors. In fact, the vast majority of patients who undergo resection of an inferior vermian or fourth ventricular tumor through an inferior vermian incision experience neither mutism nor even severe dysarthria postoperatively. In addition, in our Patients 5 and 11, the lesions were located within the superior vermis and were resected without violating the inferior vermis. Moreover, patients who have undergone complete section of the vermis may manifest little if any postoperative speech impairment (25). This implies that if an anatomic substrate for this syndrome is present within the cerebellum, it does not reside within the vermis but instead is localized more laterally.

Second, the observation that symptoms often develop after an interval of 1 to 3 days postoperatively indicates that the structures responsible for the syndrome do not generally suffer direct injury or infarction intraoperatively. This also indicates that the area responsible for the symptom complex is not directly in the midline. If the midline cerebellar structures themselves played an essential role in speech control, these should be affected immediately, rather than in a delayed fashion.

Third, the fact that the postoperative imaging studies that were performed in the children in this series showed no evidence of discrete areas of infarction, hypoperfusion, or decreased metabolic activity within the cerebellar hemispheres, diencephalon, or cerebral cortex implies that the lesion responsible for the mutism is not located at a distant site within the brain but probably resides close to the operative bed within the medial portions of the cerebellum or brain stem. In this context, our observation that patients with mutism had a significantly increased incidence of bilateral edema within the cerebellar peduncles in comparison with unaffected children is of particular interest. This implies that a critical pathway responsible for initiating speech and other complex voluntary movements travels within this structure. It can also be inferred that injury or edema occurring proximally or distally along such a pathway could induce a similar syndrome. In this regard, Frim and Ogilvy (16) noted "cerebellar" mutism in a child who underwent a subtemporal approach to a cavernous angioma within the central pons. Conversely, bilateral injury or impairment of the paramedian cerebellar relay nuclei might produce an identical syndrome in the absence of involvement of either the peduncles or brain stem. The plausibility of this mechanism is supported by the results of stereotactic lesioning studies, in which mutism has been reported as a complication of bilateral lesions to the region of the dentate nuclei (15, 18, 34). This would also account for the presence of mutism in the patients in our series without evidence of significant edema within the brain stem or peduncles.

These observations suggest that the overall symptom complex may reflect the sequelae of injury to the afferent and/or efferent pathways to the dendate nuclei, which are involved in initiating volitional movements. This pathway includes projections from the premotor and supplementary motor cortices via the brachium pontis and projections back to these areas via the dentatothalamocortical system (2, 4, 26). Thus, this syndrome may result from bilateral impairment of either the paramedian cerebellar deep nuclei (i.e., the dendate nuclei), the afferent or efferent connections to this region, or some combination thereof. That this pathway can be affected at several sites fits with our observation that there is no single abnormality revealed by imaging that is pathognomic for this syndrome. The delayed onset of the speech impairment probably reflects the interval until the edema resulting from manipulation within the operative bed has reached these structures. Because this syndrome does not occur after unilateral cerebellar exposures, it can be inferred that bilateral impairment of this pathway is necessary to produce significant deficits. However, our observation that several patients without postoperative speech impairment had evidence of edema within the cerebellar peduncles bilaterally and/or brain stem, whereas others with mutism had comparatively unimpressive postoperative imaging studies, suggests that there is substantial variability among patients in the presence and severity of speech impairments that result from apparently similar injuries to the cerebellar pathways. This view is in keeping with the results of Lechtenberg and Gilman (25) and Ackermann et al. (1), with regard to the pattern of speech deficits after ischemic, neoplastic, and traumatic injuries to the cerebellum.

It is also apparent from our own patients and a review of the literature that the duration of the speech impairment and the spectrum of associated neurological and neurobehavioral abnormalities vary widely among affected patients. In the most limited manifestation of this process, patients have impairment in coordinating the complex bilaterally integrated movements necessary to produce speech. More severe expressions of this syndrome affect not only speech but also coordination of oropharyngeal movements necessary for initiating chewing and swallowing, producing an oropharyngeal motor apraxia (11). In the most severe expression of this syndrome, initiation of a broad spectrum of volitional movements is impaired, including eye opening, voiding, and a variety of other activities. This more global impairment is apparent not only clinically but also on the basis of neuropsychiatric testing. The implication of this hypothesis is that isolated cerebellar mutism may involve a comparatively focal bilateral lesion to the dendate nuclei or their afferent or efferent pathways, whereas the more extensive manifestations of oropharyngeal apraxia and global impairment of volitional movements involve progressively more extensive involvement of the paravermian region and/or its connections. In accordance with this view, the deficits that resolve first in patients with the most severe symptoms are usually those that involve global akinesia with apparent withdrawal and urinary retention. Second, eating improves. During this stage, patients will often appear to be relatively normal other than their speech difficulties, but they still manifest subtle impairments in initiation of complex activities on detailed testing. Finally, the speech begins to recover, initially with a dysarthric and often bizarre vocal quality, and ultimately returns almost to normal.

The anatomic basis for the bizarre affective symptoms that are sometimes associated with the mutism symptom complex

remains uncertain; the emotional lability and periods of inconsolability are difficult to account for strictly on the basis of an injury to the cerebellum. Although it is conceivable that the affective symptoms simply reflect the patient's extreme frustration and sense of despondency at not being able to communicate verbally or to easily initiate voluntary movements, the almost stereotypical appearance of the affected patients, which in many ways resembles the affective state of elderly patients with multiple lacunes, suggests that a behavioral process is unlikely to be strictly involved and that a pathophysiological process is more likely responsible. Our observation that patients with this "pseudobulbar syndrome" (38) often had evidence of edema bilaterally within the cerebellar peduncles and/or brain stem suggests that these manifestations may reflect temporary dysfunction of the brain stem tegmentum. In support of this explanation, unusual personality changes are well-described manifestations of primary brain stem lesions, such as intrinsic brain stem gliomas (29), central pontine myelinolysis (30), and vascular insufficiency from proximal basilar artery ischemia (8). Although bacterial or aseptic meningitis can also produce personality changes after posterior fossa surgery and have been suggested in previous studies to be a possible precipitating factor for the development of mutism and neurobehavioral symptoms (14, 23, 31), this explanation did not account for the symptoms noted in the present series. None of our patients had evidence of bacterial meningitis or significant cerebrospinal fluid leukocytosis. In addition, high-dose steroids were administered to several patients and were ineffective in reversing either the mutism or behavioral changes, which suggests that these symptoms were not caused by aseptic meningitis.

In light of the above observations, we expect that the incidence of the mutism-pseudobulbar syndrome could be minimized by limiting the extent of manipulation around the tumor bed. Although we have made a conscious effort during the last 18 months to minimize the length of the vermian incision, an approach that has also been recommended by Dailey and Berger (11), in hope of decreasing the degree of edema and/or injury to the midline and paramedian cerebellar structures, this has not eliminated the problem. Patients 11 and 12 developed mutism despite these measures. Because the primary source of edema/injury probably results from lateral dissection and removal of tumor that is adherent to or invading the cerebellar peduncles and medial cerebellar hemispheres bilaterally, the only obvious way to avoid this syndrome is to limit aggressive tumor resection in these regions. However, because the duration of progression-free survival correlates strongly with extent of resection for astrocytoma (19), ependymoma (28, 36), and medulloblastoma (7, 24), the three most common vermian tumors, we do not advocate limiting the lateral tumor resection to avoid the potential for mutism, particularly because the mutism-pseudobulbar symptom complex is generally reversible. In contrast, extensive brain stem invasion, which also occurs in certain of these tumors, may indeed pose a practical limit to the extent of resection that can be achieved because the neurological morbidity incurred from attempting a complete or nearly complete resection is often irreversible.

SUMMARY

Mutism and associated impairments of oropharyngeal coordination and, in some cases, global impairment of volitional movements occur in a small but significant percentage of patients who undergo resection of vermian tumors. The pattern of symptoms ranges from isolated impairment of speech to oropharyngeal apraxia to global impairment in the initiation of volitional activities. In most cases, this syndrome is self-limited and relatively normal speech is recovered within 3 to 4 months. Although during the last 18 months we made a conscious effort to minimize the extent of the vermian incision, we have still encountered this syndrome in two patients (Patients 11 and 12) with large lesions exposed through comparatively limited vermian incisions. Thus, this syndrome may not result directly from the incision itself but from edema around the resection cavity, which may reversibly compromise the functioning of the dentate nuclei and or afferent or efferent connections to this region bilaterally.

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REFERENCES

1. Ackermann H, Vogel M, Petersen D, Poremba M: Speech deficits in ischaemic cerebellar lesions. **J Neurol** 239:223–227, 1992.
2. Adams RD, Victor M: The cerebellum, in: *Principles of Neurology*. New York, McGraw-Hill, ed 5, 1993, pp 74–82.
3. Aguiar PH, Plese JPP, Ciquini O, Marino R Jr: Cerebellar mutism after removal of a vermian medulloblastoma: Literature review. **Pediatr Neurosurg** 19:307, 1993 (abstr).
4. Allen GI, Tsukahara N: Cerebrocerebellar communication systems. **Physiol Rev** 54:957–1006, 1974.
5. Ammirati M, Mirzai S, Samii M: Transient mutism following removal of a cerebellar tumor: A case report and review of the literature. **Childs Nerv Syst** 5:12–14, 1989.
6. Boratynski W, Wocjan J: Mutism after surgeries with removal of posterior cranial fossa neoplasms. **Neurol Neurochir Pol** 27:261–265, 1993.
7. Bourne JP, Geyer R, Berger M, Griffin B, Milstein J: The prognostic significance of postoperative residual contrast enhancement on CT scan in pediatric patients with medulloblastoma. **J Neurooncol** 14:262–270, 1992.
8. Caplan LR: "Top of the basilar" syndrome. **Neurology** 30:72–79, 1980.
9. Catsman-Berrevoets CE, van Dongen HR, Zwetsloot CP: Transient loss of speech followed by dysarthria after removal of posterior fossa tumour. **Devel Med Child Neurol** 34:1102–1109, 1992.
10. Cochrane DD, Gustavsson B, Poskitt KP, Steinbok P, Kestle JRW: The surgical and natural morbidity of aggressive resection of posterior fossa tumors in childhood. **Pediatr Neurosurg** 20:19–29, 1994.

10a. Crutchfield JS, Sawaya R, Meyers CA, Moore BD III: Postoperative mutism in neurosurgery: Report of two cases. **J Neurosurg** 81:115–121, 1994.

11. Dailey A, Berger MS: The pathophysiology of oropharyngeal motor apraxia and mutism following resection of posterior fossa tumors in children. **J Neurosurg** 80:384, 1994 (abstr).
12. D'Avanzo R, Scuotto A, Natale M, Scotto P, Cioffi FA: Transient "cerebellar" mutism in lesions of the mesencephalo-cerebellar region. **Acta Neurol** 15:289–296 1993.
13. Dietze DD Jr, Mickle JP: Cerebellar mutism after posterior fossa surgery. **Pediatr Neurosurg** 16:25–31, 1990.
14. Ferrante L, Mastronardi L, Acqui M, Fortuna A: Mutism after posterior fossa surgery in children: Report of three cases. **J Neurosurg** 72:959–963, 1990.
15. Fraoli B, Guidetti B: Effect of stereotactic lesions of the dendate nucleus of the cerebellum in man. **Appl Neurophysiol** 38:81–90, 1975.
16. Frim DM, Ogilvy CS: Mutism and cerebellar dysarthria after brain stem surgery: Case report. **Neurosurgery** 36:854–857, 1995.
17. Gaskill SJ, Marlin AE: Transient eye closure after posterior fossa tumor surgery in children. **Pediatr Neurosurg** 17:196–198, 1991–1992.
18. Guidetti B, Fraoli B: Neurosurgical treatment of spasticity and dyskinesias. **Acta Neurochir Suppl (Wien)** 24:27–39, 1977.
19. Hayostek CJ, Shaw EG, Scheithauer B, O'Fallon JR, Weiland TL, Schomberg PJ, Kelly PJ, Hu TC: Astrocytomas of the cerebellum: A comparative clinicopathologic study of pilocytic and diffuse astrocytomas. **Cancer** 72:856–869, 1993.
20. Herb E, Thyen U: Mutism after cerebellar medulloblastoma surgery. **Neuropediatrics** 23:144–146, 1992.
21. Hirsch JF, Renier D, Czernichow P, Benveniste L, Pierre-Kahn A: Medulloblastoma in childhood: Survival and functional results. **Acta Neurochir (Wien)** 48:1–15, 1979.
22. Holmes G: The symptoms of acute cerebellar injuries due to gunshot injuries. **Brain** 40:461–535, 1917.
23. Humphreys RP: Mutism after posterior fossa tumor surgery, in Marlin AE (ed): *Concepts in Pediatric Neurosurgery*. Basel, Karger, vol 9, 1989, pp 57–64.
24. Jenkin D, Goddard K, Armstrong D, Becker L, Berry M, Chan H, Doherty M, Greenberg M, Hendrick B, Hoffman H: Posterior fossa medulloblastoma in childhood: Treatment results and a proposal for a new staging system. **Int J Radiat Oncol Biol Phys** 19:265–274, 1990.
25. Lechtenberg R, Gilman S: Speech disorders in cerebellar disease. **Ann Neurol** 3:285–290, 1978.
26. Leiner HC, Leiner AL, Dow RS: Does the cerebellum contribute to mental skills? **Behav Neurosci** 100:443–454, 1986.
27. Nagatani K, Waga S, Nakagawa Y: Mutism after removal of a vermian medulloblastoma: Cerebellar mutism. **Surg Neurol** 36: 307–309, 1991.
28. Nazar GB, Hoffman HJ, Becker LE, Jenkin D, Humphreys RP, Hendrick EB: Infratentorial ependymomas in childhood: Prognostic factors and treatment. **J Neurosurg** 72:408–417, 1990.
29. Petronio JA, Edwards MSB: Management of brain stem tumors in children. **Contemp Neurosurg** 11:1–6, 1989.
30. Price BH, Mesulam MM: Behavioral manifestations of central pontine myelinolysis. **Arch Neurol** 44:671–673, 1987.
31. Rekate HL, Grubb RL, Aram DM, Hahn JF, Ratcheson RA: Muteness of cerebellar origin. **Arch Neurol** 42:697–698, 1985.
32. Sakai H, Sekino H, Nakamura N: Three cases of "cerebellar mutism." **Shinkeinaika** 12:302–304, 1980.
33. Salvati M, Missori P, Lunardi P, Orlando ER: Transient cerebellar mutism after posterior fossa surgery in an adult: Case report and review of the literature. **Clin Neurol Neurosurg** 93:313–316, 1991.
34. Siegfried J, Esslen E, Gretener U, Ketz E, Perret E: Functional anatomy of the dendate nucleus in the light of stereotaxis operations. **Confin Neurol** 32:1–10, 1970.
35. Van Dongen HR, Catsman-Berrevoets CE, van Mourik M: The syndrome of "cerebellar" mutism and subsequent dysarthria. **Neurology** 44:2040–2046, 1994.
36. Vanuytsel LJ, Bessell EM, Ashley SE, Bloom HJG, Brada M: Intracranial ependymoma: Long-term results of a policy of surgery and radiotherapy. **Int J Radiat Oncol Biol Phys** 23:313–319, 1992.
37. Volcan I, Cole GP, Johnston K: A case of muteness of cerebellar origin. **Arch Neurol** 43:313–314, 1986 (letter).
38. Wisoff JH, Epstein FJ: Pseudobulbar palsy after posterior fossa operation in children. **Neurosurgery** 15:707–709, 1984.
39. Yonemasu Y: Cerebellar mutism and speech disturbances as a complication of posterior fossa surgery: Presented at the 13th Annual Meeting of the Japanese Society for Pediatric Neurosurgery. Tsukuba, Japan, 1995.

COMMENTS

The authors review all of the cases of mutism that have been published up until this time and add 12 patients of their own. The vast majority of cases of mutism involve the cerebellar vermis. The imaging studies the authors report show that there is a significant degree of edema in the brachium pontis, which has led them to implicate the dentate nuclei as the cause of this entity of mutism. Furthermore, Crutchfield et al. (1) have theorized that bilateral interruption of the dentatothalamocortical pathway may be responsible for postoperative mutism.

I was surprised at the high incidence of mutism in the authors' institution. Mutism after posterior fossa surgery in our institution is rare, and I personally have never had a case of mutism after posterior fossa surgery. The authors speculate that aggressive lateral dissection, which may produce edema in the region of the dentate nuclei, may be the cause of this condition. Conceivably, a more gentle removal of these posterior fossa tumors may do away with this bizarre syndrome.

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1. Crutchfield JS, Sawaya R, Meyers CA, Moore BD: Postoperative mutism in neurosurgery. J **Neurosurg** 81:115–121, 1994.

This article describes a well-known syndrome of psychological changes and mutism after exploration of the posterior fossa and removal of tumor, particularly in the presence of hydrocephalus. Although the syndrome is well known to most of us dealing with the pediatric population, it is still mystifying because the actual locus of the lesion, the physiopathology, and the treatment have not been demonstrated. In this presentation, an attempt is made to review the present knowledge of this disorder, and there is an excellent review of the pertinent literature.

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