# Corpus Callosum Swelling after Resection of Intraventricular Central Neurocytoma

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## Abstract

Corpus callosum swelling has been reported to occur after ventriculoperitoneal shunting for long-standing hydrocephalus. This report presents a case of corpus callosum swelling after intraventricular tumor resection. A 34-year-old woman presented with a headache that worsened over 1 month. Magnetic resonance (MR) images revealed a mass lesion in the left lateral ventricle and obstructive hydrocephalus. She underwent subtotal resection with a transcallosal approach. After tumor resection, she had long-lasting status epilepticus followed by consciousness disturbance. T2-weighted MR images obtained 8 hr after the operation showed a hyperintense area in the corpus callosum. The patient then presented with bilateral dilated pupils 14 hr after the operation due to acute hydrocephalus and tension pneumocephalus. An emergent re-craniotomy was performed and a ventricular drain was placed. The patient recovered consciousness 3 days after the operation. However, she experienced progressive corpus callosum swelling 25 days after the operation, which improved since then. Approximately 4 months after the operation, she returned to her usual workplace with no neurocognitive functional decline. Two years later, she was doing well with no radiological abnormal findings except corpus callosum thinning. Thus, corpus callosum swelling can develop not only after shunting for chronic hydrocephalus but also after intraventricular tumor resection. It occurred relatively acutely and there was no decline in intelligence after long-term follow-up. This case suggests that corpus callosum swelling after intraventricular tumor resection is a rare but noteworthy complication that can improve without intervention.

Keywords: corpus callosum, swelling, tumor resection, central neurocytoma, long-term outcomes

## Introduction

The corpus callosum with approximately 180 million callosal fibers is the largest commissure between bilateral hemispheres.[1] Injury to corpus callosum fibers due to stroke, trauma, or surgical procedures can cause callosal disconnecting syndrome.[2,3] Recently, it has been reported that ventriculoperitoneal shunting for obstructive and communicating hydrocephalus can induce an abnormal appearance of the corpus callosum in 3.1%–11.3% of patients.[4–11] These abnormal changes included swelling of the corpus callosum and a scalloping deformity of the dorsal surface of the body of the corpus callosum.[6] These abnormal findings do not usually accompany the neurological symptoms themselves and biopsy or intervention was not necessary.

This report presents a case of corpus callosum swelling after resection of an intraventricular central neurocytoma. This is the first report demonstrating that corpus callosum swelling can occur after a transcallosal approach to the intraventricular tumor as well as post-shunting. Detailed radiological findings during the swelling and functional outcomes and radiological findings after long-term follow-up are also presented.
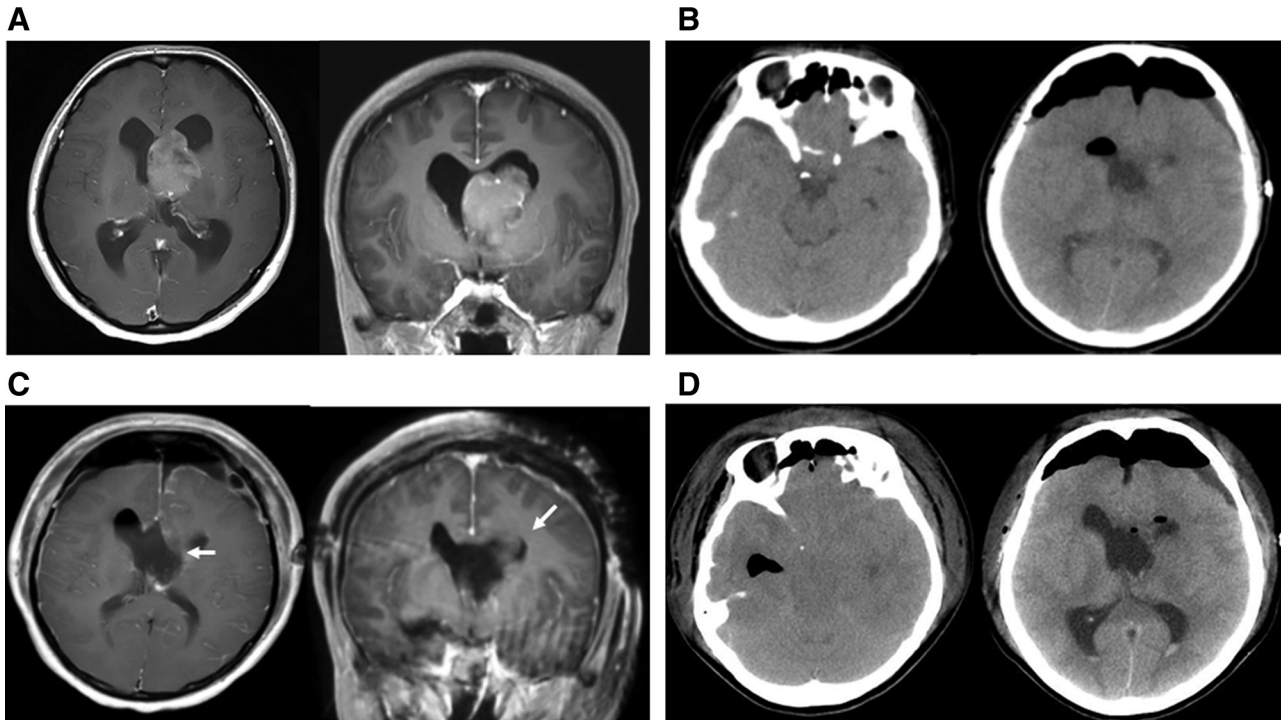
**Fig. 1** (A) Preoperative axial (left) and coronal (right) T1-weighted magnetic resonance (MR) images after the administration of contrast media showing the presence of a lesion in the left lateral ventricle. (B) CT immediately after tumor resection showed no hemorrhagic complications or postoperative acute hydrocephalus but trapped air in the frontal area was present. (C) Axial (left) and coronal (right) T1-weighted MRI 8 hr after the operation after the administration of contrast media showing the residual lesion (arrow) and the absence of postoperative acute hydrocephalus. (D) CT 14 hr after the operation showing enlargement of the lateral ventricle and central trans-tentorial herniation.

## Case Report

A 34-year-old right-handed woman presented with a headache that worsened over 1 month. She was alert and focal neurologic signs were not noted. T1-weighted magnetic resonance (MR) images after administration of contrast media revealed a mass lesion that was 40 mm maximal in diameter in the left lateral ventricle (Fig. 1A). Mild thinning of the corpus callosum, especially in the posterior body of the corpus callosum, and obstructive hydrocephalus were noted (Figs. 1A and 2A). Based on MRI findings, the preoperative diagnosis was central neurocytoma.

Because the lesion was located on the left side and there were no bridging veins to interfere with an interhemispheric approach, the tumor was resected with an interhemispheric transcallosal approach. The patient underwent subtotal resection with a transcallosal approach including cutting 2 cm of the corpus callosum. The tumor was a reddish, hypervascular lesion that originated around the foramen of Monro. A subtotal resection was performed, leaving the lateral part of the tumor unexposed from the callosal window. During tumor resection,

deep veins, pericallosal arteries, and the corpus callosum, other than the surgical route, were preserved.

Immediately after tumor resection, the patient had long-lasting status epilepticus. Hemorrhagic complications and postoperative hydrocephalus were not observed, but CT conducted immediately after the tumor resection showed trapped air at the frontal area (Fig. 1B). The administration of diazepam, levetiracetam, and phenobarbital relieved the epilepsy, but consciousness disturbance resulted thereafter. She was diagnosed with post-ictal consciousness disturbance. MR images obtained 8 hr after the operation indicated that subtotal resection of the mass lesion did not induce damage to the thalamostriate vein, ischemic lesion, or postoperative acute hydrocephalus (Fig. 1C). In T2-weighted MR images, however, a hyperintense area in the posterior part of the body of the corpus callosum, far from the resection site, and moderate effacement of the basal cistern were noted (Fig. 2B). The patient went into a deep coma with bilateral dilated pupils without light reflex 14 hr after the operation. CT demonstrated ventricular enlargement and central trans-tentorial
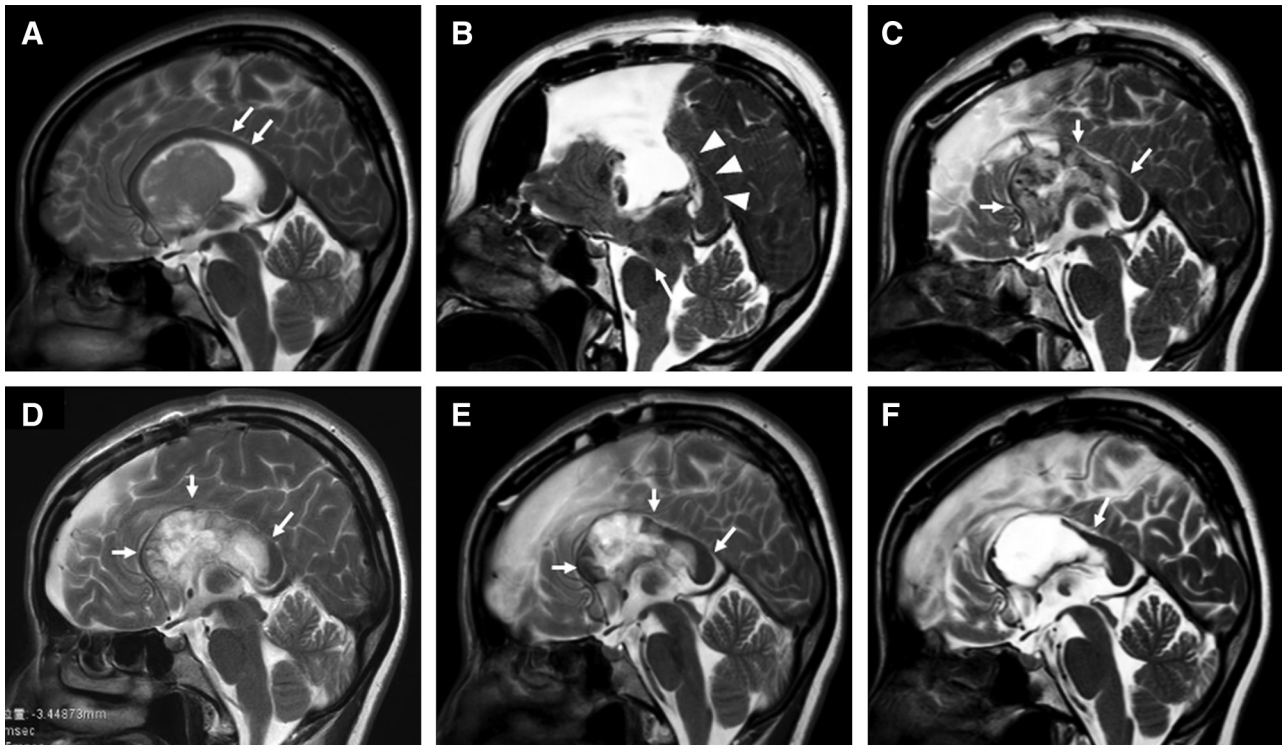
Fig. 2　Serial sagittal magnetic resonance images showing the preoperative corpus callosum (arrows, thinning of the posterior body of the corpus callosum) (A) and signal changes and subsequent corpus callosum appearance at 8 hr after the tumor resection (arrowheads, signal changes of the corpus callosum; arrow, moderate effacement of the basal cistern) (B) and 3 days (C) and 25 days (D) after tumor resection. This finding was improved at 41 days (arrows in C–E, signal changes and swelling of the corpus callosum) (E) after the operation and disappeared completely with thinning of the corpus callosum after 2 years (arrow, atrophy of the posterior body of the corpus callosum) (F).

herniation (Fig. 1D). These changes were thought to be associated with a combination of acute hydrocephalus and persistent tension pneumocephalus (Fig. 1D). An emergent re-craniotomy was then performed. During the second operation, significantly elevated intracranial pressure was observed and a cerebral ventricular drain was placed. The patient fully recovered consciousness 3 days after the operation. Ventricular drainage was removed at 12 days after the operation. However, she experienced progressive corpus callosum swelling 25 days after the operation (Fig. 2C and 2D). Diffuse corpus callosum swelling with cyst formation was observed in the rostrum, genu, and body of the corpus callosum sparing splenium (Figs. 2D and 3A). On an apparent diffusion coefficient (ADC) map, the value of ADC was mostly increased in the rostrum, genu, and body of the corpus callosum and was partially decreased in the genu of the corpus callosum (Fig. 3A). Based on the findings from T1- and T2-weighted images, T2* images, and the ADC map, the main cause of corpus callosum swelling was thought to be interstitial edema, and hemorrhagic and ischemic changes

were partly involved. ADC map and tractography based on diffusion tensor (DT) imaging revealed elevated ADC values and preserved directionality (Fig. 3B). At that time, the patient's neurologic findings did not deteriorate; hence, conservative treatment was performed. Repeated MR images obtained 41 days after the operation revealed that corpus callosum swelling had improved (Fig. 2E) and she was discharged 52 days after the operation. Four months after the operation, the abnormal signals disappeared (data not shown) and she returned to her usual workplace. She was followed every 4 months thereafter and was doing well. Two years after the operation, MR images showed thinning of the corpus callosum, notably in the area where the swelling was initially found (Fig. 2F). However, the fibers of splenium at 2 years after the operation were seen more clearly due to the improvement of interstitial edema. We considered that the directionality of the corpus callosum was preserved after 2 years of follow-up (Fig. 3C).

We estimated serial intelligence with the Wechsler Adult Intelligence Scale, third edition (WAIS-III), before the operation and at 53 days and 2 years
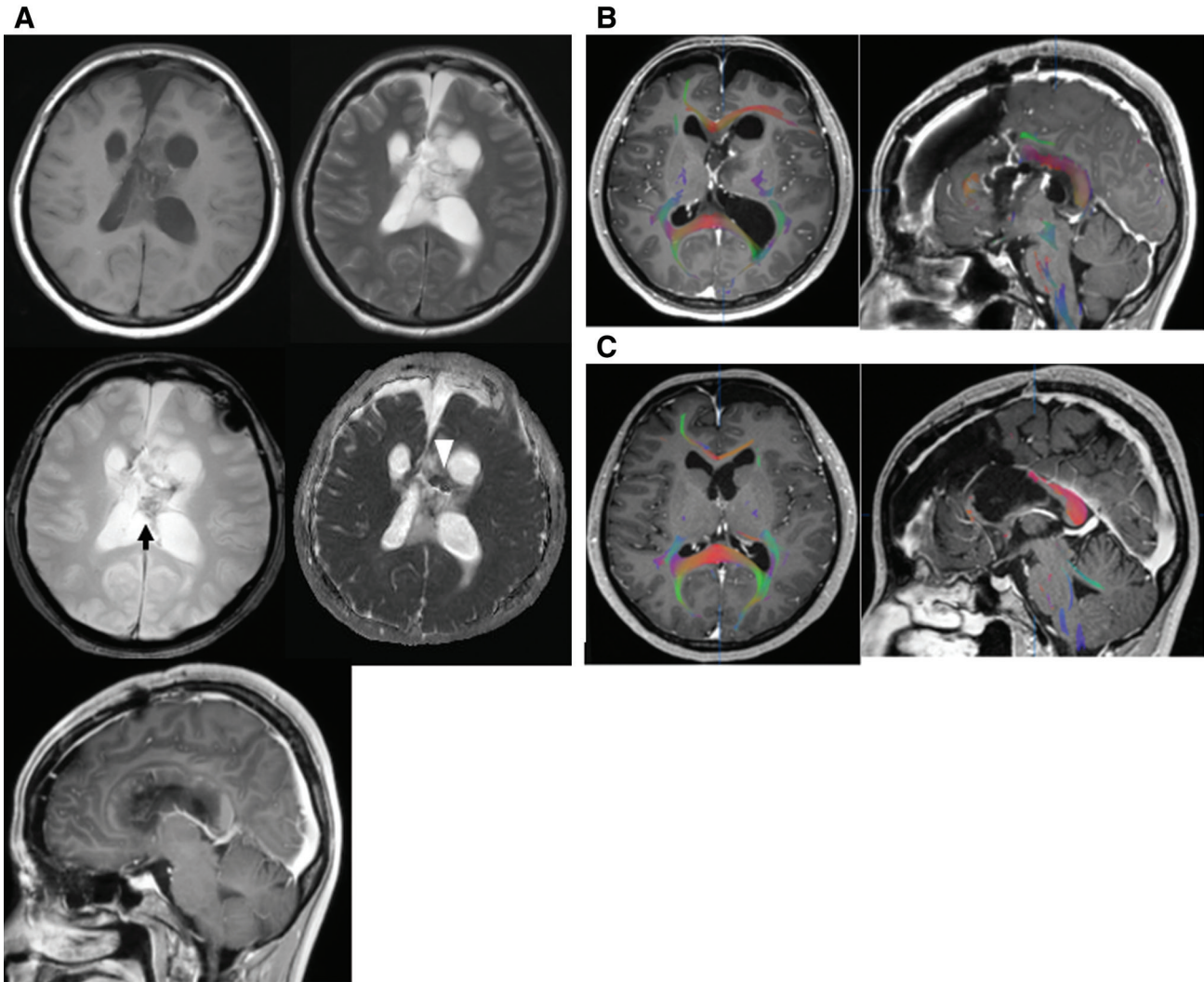
**Fig. 3** **(A) Axial T1-weighted (upper left), T2-weighted (upper right), and T2\*-weighted MRI, apparent diffusion coefficient map (middle left), and sagittal T1-weighted MRI (bottom) after the administration of contrast media, showing the nature and distribution of the corpus callosum swelling (arrow, hemorrhagic changes; arrowhead, ischemic changes). Tractography of the corpus callosum, showing the preserved directionality of the corpus callosum at 25 days (B) and 2 years (C) after the operation.**

after the operation. There was no regrowth of the residual tumor until the last follow-up. Her verbal intelligence quotient (IQ), performance IQ, full-scale IQ, and the indices of verbal comprehension, perceptive organization, working memory, and process speed are shown in Supplemental Table 1 (The supplementary table is available online.) These scores were not lower at each postoperative period compared to the preoperative score.

## Discussion

This report describes a case of corpus callosum swelling after resection of an intraventricular central neurocytoma. Radiological findings were noted as

early as 8 hr after the operation as a signal change of the ventral surface of the body of the corpus callosum, which was followed by swelling until 25 days after the resection. Thereafter, this finding improved within 4 months. Although the body of the corpus callosum became slightly thinner after long-term follow-up compared to before the operation, neurocognitive functions and corpus callosum directionality were preserved for 2 years after the operation. To the best of our knowledge, this is the first report describing corpus callosal swelling after resection of a central neurocytoma with an interhemispheric transcallosal approach.

Swelling or a scalloping deformity of the corpus callosum is a rare but noteworthy finding after

shunting. Table 1 summarizes the clinical characteristics of the patients with abnormal signals of the corpus callosum after shunting. This phenomenon can occur at all ages, from children to the elderly. All of them developed swelling or a scalloping deformity of the corpus callosum after shunting, but none had this after drainage or shunting to acute hydrocephalus.[6] Most patients had neoplastic or non-neoplastic obstructive hydrocephalus before shunting and the causes of hydrocephalus were aqueduct stenosis in ten[4,8–10] and tectal tumors in seven.[4,6,9,10] Other etiologies of obstructive hydrocephalus were thalamic astrocytoma,[4] fourth ventricular tumors,[4] multiple ependymoma,[9] clivus meningioma,[9] arachnoid cysts,[4] Chiari type I malformations,[6] and choroidal cysts.[9] Otherwise, shunting to communicating hydrocephalus developed, including idiopathic normal pressure hydrocephalus[5] or through an unknown congenital mechanism.[7] On MRI, corpus callosum swelling and a scalloping deformity of the corpus callosum were reported in five and nine patients, respectively. These findings always involved the body of the corpus callosum and spared the splenium in most of the patients. Intervals between shunting and the appearance of abnormal findings ranged from 2 days to 75 months.[4,7] These findings persisted for more than 3 months to 5 years in some patients, whereas they were reversible within 6 weeks to 16 months after shunting in other patients.[4–10] All patients with reversible abnormal findings of the corpus callosum had hydrocephalus caused by a tumor including a glioblastoma, astrocytoma, ependymoma, and meningioma. In these patients with reversible findings, signal changes appeared relatively early, ranging from 2 weeks to 2 months.[6,9] They did not result in a disconnecting syndrome or neurocognitive dysfunction.[5,8,10]

From these clinical findings and an autopsy study, the mechanism for a scalloping deformity of the corpus callosum was proposed as the "tethering theory."[6] According to this hypothesis, long-standing hydrocephalus can cause significant dilation of ventricles and elevation of the body of the corpus callosum compared to acute hydrocephalus.[4,8–11] After shunting, the body of the corpus callosum was relaxed and sagged caudally but the body of the corpus callosum was tethered by the rami of the pericallosal artery. This may explain the mechanism of the scalloping deformity of the corpus callosum.[4,6,7] The splenium was spared from signal changes because it did not sag caudally.[6] However, this was insufficient for explaining the mechanism for corpus callosum swelling. In this regard, Suh et al. postulated a mechanism for swelling in which

the elevated corpus callosum impinged against a rigid falx and the softening of the corpus callosum resulted in edema, ischemia, and loss of myelinating fibers of the corpus callosum.[10]

Since our patient had direct invasion to the corpus callosum and vasculature around the corpus callous as well as drastic and acute pressure changes caused by postoperative hydrocephalus and pneumocephalus during the perioperative period, there could be a unique mechanism for corpus callosum swelling. However, the surgical invasions seemed to not play an important role in corpus callosum swelling because the site of signal changes occurred far from the incision of the corpus callosum and the diffuse corpus callosum swelling sparing the splenium was not anatomically inconsistent to the area of arterial supply or venous drainage. The perioperative pressure changes also seemed to be unlikely as the mechanism for corpus callosum swelling because these changes did not occur in acute hydrocephalus[6] and the signal changes occurred before the onset of acute hydrocephalus in our case. On the contrary, the finding of ventricular dilatation with thinning of the posterior body of the corpus callosum (Fig. 2A) suggested chronic hydrocephalus and the long-standing impingement of the corpus callosum to the falx.[11] Under this condition, surgical opening of the ventricle by cutting the corpus callosum could have a similar effect to shunting. The MR findings, including T1-, T2-, and T2*-weighted MR images as well as the ADC map, indicated that the main nature of this change was interstitial edema, and this was consistent with the hypothesis proposed by Suh et al.[10] In this way, the main cause of corpus callosum swelling in our patient was considered to be chronic hydrocephalus and decompression of the corpus callosum when the ventricle was opened.

Consistent with previous reports,[5,7,8,10] this study confirmed the preservation of both intelligence short term and long term after improvement of the corpus callosum swelling and corpus callosum white matter fiber tracts by tractography, fused with gadolinium enhanced T1-weighted imaging, obtained during corpus callosum swelling. In a previous report,[10] neurocognitive functions were preserved 4–5 years after shunting for hydrocephalus caused by aqueduct stenosis or a tectal tumor based on comprehensive estimation of neurocognitive functions including intelligence, memory, frontal lobe function, motor function, and attention. DT imaging is a technique that can delineate the major fiber tracts in the corpus callosum.[12,13] Unlike diffusion in a glass of pure water, which would be the same in all directions, the diffusion measured in tissue varies with direction. In the white matter of the brain, diffusion

Table 1   Characteristics of the patients with development of abnormal signals of the corpus callosum after shunting and our case

| Type of hydrocephalus | Authors | Age and sex | Cause of hydrocephalus | Intervals from shunting to appearance of abnormal finding | Type of abnormal findings | Site of corpus callosum with abnormal signals | Follow-up findings (interval from shunting) | Functional outcomes (interval from shunting to estimation) |
|---|---|---|---|---|---|---|---|---|
| Communicating hydrocephalus | Numaguchi et al.[6] | 45 M | Unknown | 1 month | Scalloping deformity | Body | N.D. | N.D. |
| | Ginat et al.[7] | 5 F | Unknown | 4 years | Scalloping deformity/ swelling | Body | No change (4.5 years) | N.D. |
| | Mullaguri et al.[5] | 64 F | iNPH | 2 years | N.D. | Genu, body, splenium | No change (3 years) | No decline in neurocognitive function (4 years) |
| Obstructive hydrocephalus (non-neoplastic lesion) | Spreer et al.[9] | N.D. | Aqueduct stenosis | 2 days | N.D. | N.D. | No change (5 months) | N.D. |
| | | N.D. | Aqueduct stenosis | 6 weeks | N.D. | N.D. | No change (3 months) | N.D. |
| | | N.D. | Aqueduct stenosis | 9 days | N.D. | N.D. | No change (3 weeks) | N.D. |
| | Suh et al.[10] | 45 M | Aqueduct stenosis | 8 months | Swelling | Genu, body | No change (5 years) | Normal in neuropsychological examinations (5 years) |
| | Constantinescu et al.[8] | 19 M | Aqueduct stenosis | 4 weeks | Swelling | Genu, body, splenium | No change (15 months) | Normal in neuropsychological examinations (15 months) |
| | Lane et al.[4] | 72 F | Aqueduct stenosis | 5 months | Scalloping deformity | Body | N.D. | N.D. |
| | | 9 F | Aqueduct stenosis | 36 months | N.D. | Body | N.D. | N.D. |
| | | 69 F | Aqueduct stenosis | 39 months | N.D. | Genu, body | N.D. | N.D. |
| | | 48 F | Aqueduct stenosis | 75 months | N.D. | Body | N.D. | N.D. |
| | | 67 M | Aqueduct stenosis | 8 months | N.D. | Genu, body | N.D. | N.D. |
| | | 30 M | Arachnoid cyst compressing aqueduct | 27 months | N.D. | Body | N.D. | N.D. |
| | Numaguchi et al.[6] | 46 F | Chiari type I malformation | 13 months | Scalloping deformity | Body | N.D. | N.D. |
| | Spreer et al.[9] | N.D. | Choroid cyst | 4 months | N.D. | N.D. | N.D. | N.D. |

(*Continued*)

**Table 1   Continued**

| Type of hydrocephalus | Authors | Age and sex | Cause of hydrocephalus | Intervals from shunting to appearance of abnormal finding | Type of abnormal findings | Site of corpus callosum with abnormal signals | Follow-up findings (interval from shunting) | Functional outcomes (interval from shunting to estimation) |
|---|---|---|---|---|---|---|---|---|
| Obstructive hydrocephalus (neoplastic lesion) | Numaguchi et al.[6] | 6 F | Tectal astrocytoma | 12 months | Scalloping deformity | Body | No change (22 months) | N.D. |
| | | 9 M | Tectal astrocytoma | 2 months | Scalloping deformity | Body | Normalization (16 months) | N.D. |
| | | 62 F | Tectal glioblastoma | 3 weeks | Scalloping deformity | Body | Normalization (3 months) | N.D. |
| | | 6 M | Tectal tumor | 1 week | Scalloping deformity | Genu, body | No change (13 months) | N.D. |
| | Spreer et al.[9] | N.D. | Tectal glioma | 2 days | N.D. | N.D. | No change (3 months) | N.D. |
| | Suh et al.[10] | 55 M | Tectal tumor | 1 month | Swelling | Body | No change (4 years) | Normal in neuropsychological examinations (4 years) |
| | | 5 F | Tectal tumor | 3 months | Scalloping deformity | Body | N.D. | N.D. |
| | | 20 F | Thalamic astrocytoma | 27 months | N.D. | Body | N.D. | N.D. |
| | Lane et al.[4] | 73 M | Fourth ventricular tumor | 3 months | Swelling | Body | N.D. | N.D. |
| | | N.D. | Clivus meningioma | 2 weeks | N.D. | N.D. | Normalization (6 weeks) | N.D. |
| | Spreer et al.[9] | N.D. | Multiple ependymoma | 8 weeks | N.D. | N.D. | Normalization (5 months) | N.D. |
| | Our case | 34 F | Central neurocytoma | 8 hr* | Swelling | Genu, body | Normalization (4 months*) | No decline in the intelligence (2 years*) |

*interval from the tumor resection. F: female, iNPH: idiopathic normal pressure hydrocephalus, M: male, N.D.: not described.

anisotropy is primarily caused by cellular membranes, with some contribution from myelination and the packing of the axons.[14] Ginat et al. demonstrated preservation of the directionality of corpus callosum white matter tracts during a scalloping deformity and swelling of corpus callosum, and they concluded that conservative management, instead of brain biopsies, lumbar punctures, and workup for toxic or metabolic leukoencephalopathies, should be performed in these cases.[7] This conclusion was applicable to the case presented here in which there was a different background and time course of corpus callosum swelling.

Recently, endoscopic resections of intraventricular central neurocytomas have been reported.[15–17] In our case, the tumor was located in the language dominant hemisphere. We therefore selected an interhemispheric transcallosal approach rather than a transcortical approach. Postoperative MR images revealed a residual lesion on the lateral side, which could have been resected with an endoscopic assisted technique as reported previously.[15] Alternatively, purely endoscopic resection with an endoscopic ultrasonic aspirator has been reported.[16] Although subtotal resection of a central neurocytoma with a purely endoscopic resection was achieved, the authors suggested that the indication was limited to a small tumor or tumors in which radical resection was not necessary.[16] It remains unclear if the corpus callosum swelling could have been avoided with a less invasive resection with an endoscope in this case. However, corpus callosum swelling may have occurred if the proposed mechanism was true.

This study had the following limitations. First, because we did not estimate neurocognitive function when swelling of the corpus callosum was prominent, it remains unclear whether corpus callosum swelling after the transcallosal approach was truly asymptomatic. Second, there have been no reports on intraventricular tumors after resection. Our studied case experienced a tentorial herniation complication; hence, the reported case here could not be generalized with cases in which tumor resection was performed with a transcallosal or transcortical approach.

In conclusion, corpus callosum swelling could develop not only after shunting for chronic hydrocephalus but also after intraventricular tumor resection. In the case presented here, relatively acute changes in corpus callosum swelling were noted, but there were no clinical symptoms observed after long-term follow-up. This report suggests that corpus callosum swelling is a rare but noteworthy complication after intraventricular tumor resection and

that intervention is not necessary for this phenomenon.

## Acknowledgments

## Conflicts of Interest Disclosure

The authors declare that they have no financial conflicts of interest. D.A., M.K., R.S., and T.T. have registered online Self-reported COI Disclosure Statement Forms through the website for JNS members.

## References

1) Devinsky O, Laff R: Callosal lesions and behavior: history and modern concepts. *Epilepsy Behav* 4: 607–617, 2003
2) Ribas EC, Yağmurlu K, de Oliveira E, Ribas GC, Rhoton A: Microsurgical anatomy of the central core of the brain. *J Neurosurg* 129: 752–769, 2018
3) Watson RT, Heilman KM: Callosal apraxia. *Brain* 106 (Pt 2): 391–403, 1983
4) Lane JI, Luetmer PH, Atkinson JL: Corpus callosal signal changes in patients with obstructive hydrocephalus after ventriculoperitoneal shunting. *AJNR Am J Neuroradiol* 22: 158–162, 2001
5) Mullaguri N, Battineni A, Newey CR, Nattanmai P: White matter changes in corpus callosum in a patient with idiopathic normal pressure hydrocephalus. *J Neurosci Rural Pract* 8: 657–659, 2017
6) Numaguchi Y, Kristt DA, Joy C, Robinson WL: Scalloping deformity of the corpus callosum following ventricular shunting. *AJNR Am J Neuroradiol* 14: 355–362, 1993
7) Ginat DT, Prabhu SP, Madsen JR: Postshunting corpus callosum swelling with depiction on tractography. *J Neurosurg Pediatr* 11: 178–180, 2013
8) Constantinescu CS, McConachie NS, White BD: Corpus callosum changes following shunting for hydrocephalus: case report and review of the literature. *Clin Neurol Neurosurg* 107: 351–354, 2005
9) Spreer J, Ernestus RI, Lanfermann H, Lackner K: Lesions of the corpus callosum in hydrocephalic patients with ventricular drainage – A CT-study. *Acta Neurochir (Wien)* 138: 174–178, 1996
10) Suh DY, Gaskill-Shipley M, Nemann MW, Tureen RG, Warnick RE: Corpus callosal changes associated with hydrocephalus: a report of two cases. *Neurosurgery* 41: 488–493; discussion 493–494, 1997
11) Jinkins JR: Clinical manifestations of hydrocephalus caused by impingement of the corpus callosum on the falx: an MR study in 40 patients. *AJNR Am J Neuroradiol* 12: 331–340, 1991

12) Huang H, Zhang J, Jiang H, et al.: DTI tractography based parcellation of white matter: application to the mid-sagittal morphology of corpus callosum. *Neuroimage* 2005; 26: 195–205, 2005

13) Jang SH, Lee J, Yeo SS, Chang MC: Callosal disconnection syndrome after corpus callosum infarct: a diffusion tensor tractography study. *J Stroke Cerebrovasc Dis* 22: e240–244, 2013

14) O'Donnell LJ, Westin CF: An introduction to diffusion tensor image analysis. *Neurosurg Clin N Am* 22: 185–196, viii, 2011

15) Fratzoglou M, Leite dos Santos AR, Gawish I, Perneczky A: Endoscope-assisted microsurgery for tumors of the septum pellucidum: surgical considerations and benefits of the method in the treatment of four serial cases. *Neurosurg Rev* 28: 39–43, 2005

16) Ibáñez-Botella G, Segura M, De Miguel L, Ros B, Arráez MÁ: Purely neuroendoscopic resection of intraventricular tumors with an endoscopic ultrasonic aspirator. *Neurosurg Rev* 42: 973–982, 2019

17) Eliyas JK, Glynn R, Kulwin CG, et al.: Minimally invasive transsulcal resection of intraventricular and periventricular lesions through a tubular retractor system: multicentric experience and results. *World Neurosurg* 90: 556–564, 2016

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