Predictors of hydrocephalus after lateral ventricular tumor resection

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Research Article

Keywords: LVT, Hydrocephalus, EVD, ventriculoperitoneal shunt

Posted Date: October 21st, 2021

DOI: https://doi.org/10.21203/rs.3.rs-936871/v1

Abstract

The aim of this study was to identify the predictors of postoperative hydrocephalus in patients with lateral ventricular tumors (LVTs) and to guide the management of perioperative hydrocephalus. We performed a retrospective analysis of patients who received LVT resection at the Department of Neurosurgery, Zhongnan Hospital of Wuhan University between January 2011 and March 2021. Patients were divided between a prophylactic external ventricular drainage (EVD) group and a non-prophylactic EVD group. We analyzed the non-prophylactic EVD group to identify predictors of acute postoperative hydrocephalus. We analyzed all enrolled patients to determine predictors of postoperative ventriculoperitoneal shunt placement. A total of 97 patients were included in this study. EVD was performed in 23 patients with postoperative acute obstructive hydrocephalus, nine patients with communicative hydrocephalus, and two patients with isolated hydrocephalus. Logistic regression analysis showed that tumor anterior invasion of the ventricle ($P = 0.020$) and postoperative hemorrhage ($P = 0.004$) were independent risk factors for postoperative acute obstructive hydrocephalus, while a malignant tumor ($P = 0.004$) was an independent risk factor for a postoperative ventriculoperitoneal shunt. In conclusion, anterior invasion of the lateral ventricle and postoperative hemorrhage are independent risk factors for acute obstructive hydrocephalus after LVT resection. Patients with malignant tumors have a greater risk of shunt dependence after LVT resection.

Introduction

Ventricular tumors refer to lesions originating in related ventricular structures or secondary ventricular neoplasms originating in periventricular tissues and most of the neoplasms (more than 2/3) invading into the ventricle(5). Resection is the main treatment for ventricular tumors(19). Tumor resection can restore the cerebrospinal fluid (CSF) circulation pathway, with some lateral ventricular tumor (LVT) patients showing relief of intracranial hypertension symptoms after resection. However, patients can also develop acute or persistent hydrocephalus after resection, with a requirement for CSF drainage(10).

Postoperative hydrocephalus includes acute obstructive hydrocephalus, communicative hydrocephalus, and isolated hydrocephalus. Many studies have reported an association between supratentorial ventricular tumors and hydrocephalus, especially in pediatric patients. By contrast, the relationship between supratentorial ventricular tumors and hydrocephalus remains unclear. Nevertheless, studies without use of regression analysis suggest that hydrocephalus after LVT resection may be related to the surgical approach, tumor location, degree of resection, and displacement of hemostatic material(6, 7, 14). Thus, the aim of the present study was to identify the predicative factors for hydrocephalus after LVT resection using regression analysis, to help identify patients at high risk of postoperative acute hydrocephalus and shunt dependence.

Materials And Methods

Study population and data collection

From January 2011 to February 2021, a total of 762 patients who were >18 years old and previously diagnosed with PFTs by outpatient computerized tomography(CT) or magnetic resonance imaging(MRI) were admitted to the Neurosurgery Department, Zhongnan Hospital of Wuhan University. Exclusion criteria were patients with non-resectable tumors, patients presenting for biopsy, patients who had a ventriculoperitoneal shunt (VP)- shunt or endoscopic third ventriculostomy (ETV) performed before resection, and patients who were found not to have a tumor postoperatively. Clinical information was recorded for all enrolled with a follow-up duration ranging from 90 days to 6 years.

Clinical data and radiological records collected were obtained from the hospital's electronic database. We recorded information on sex, age, tumor location, tumor size, pathological results, presence of preoperative or postoperative hydrocephalus, resection range, postoperative hemorrhage, perioperative external ventricular drainage (EVD), ETV, and VP- shunts.

Diagnostic criteria for hydrocephalus were symptoms of cranial hypertension and imaging results indicating Evans' index ≥30%(12).

The criteria for preoperative and postoperative EVD were acute hydrocephalus with cranial hypertension symptoms and radiographic diagnosis(8). All patients with postoperative acute hydrocephalus received EVD in our department.

The time for drainage removal was 14 days. The cretial for drainage removal were: (i) the patient was in a stable condition, with increasing of the drainage height over a few days followed by closing of the drainage for at least 12 h; and (ii) the CT scan was negative for 24 h before drainage removal. If the drainage was difficult to remove, we performed a VP-shunt. Patients with EVD caused by postoperative cerebrospinal fluid (CSF) leakage or subcutaneous effusion were excluded from this study.

The criteria for a post-resection VP-shunt were EVD weaning failure, symptomatic chronic hydrocephalus, or an isolated ventricle requiring permanent draniage, all the received cases were excluded with intracranial infection.

On the basis of preoperative MRI, we classified LVTs as either anterior invasion tumors (i.e., tumor invading the anterior part of the lateral ventricle (Fig. 1, red box or tumors without anterior invasion(i.e., tumors not invading the anterior part of the lateral ventricle. MRI images showing a typical case invading into the anterior part of the lateral ventricle are shown in Figure 2.

Tumor size was calculated using the longest axis of the maximum cross-sectional area of the tumor on MRI.

The degree of tumor resection was determined by MRI or CT within 72 h after surgery(16).

Postoperative hemorrrhage was confirmed by postoperative CT.

Statistical analysis

Data were analyzed using statistical software (IBM SPSS Statistics v22 and v24). The Student's t- test was used for comparisons between the two groups. Binary parameters were analyzed with the chi-square test. Multivariate logistic regression analysis was performed to find independent predictors of EVD placement. Odds ratios (OR) and 95% confidence intervals were calculated to assess the impact of the variables. $P < 0.05$ was considered statistically significant.

Results

Patient characteristics

Ninety-seven of the 112 patients were enrolled, with 15 patients excluded due to inclusion/exclusion criteria, including six patients without resection, five patients with loss of postoperative follow-up, two patients with multiple intracranial tumors, one patient with a biopsy, one patient with a pre-resection VP-shunt, two patients with simultaneous invasion of subtentorial part, 2 cases with a postoperative diagnosis of brain abscess.

The average age of the enrolled patients was 42.2 year (range, 6-79 years), with 47 male patients (48.5%) and 50 females patients (51.5%). Pathological results showed 32 patients with meningiomas, 21 patients with central neurocytomas, 18 patients with gliomas, 11 patients with ependymomas, 5 patients with choroid plexus papillomas, 3 patients with hemangiomas, 2 patients with germinoma, 5 patients with other pathological results. Among these patients, 31 received prophylactic EVD before or during surgery, 10 of the 66 patients without prophylactic EVD developed acute hydrocephalus and received EVD after tumor resection, and 11 of all patients received post-operative VP-shunt. The tumor pathology and location data for the patients are shown in Table 1.

Predicators of posotoperative acute hydrocephalus

The average age of the 66 patients without prophylactic EVD was 46.1 years, (range, 12-72 years), with 34 male patients (51.5%) and 32 female patients (48.5%). Pathological results showed 31 patients with benign tumors (47.0%) and 35 patients with malignant tumors (53.0%).

In univariate analysis, tumor location (P=0.039), resection degree(P=0.013), postoperative hemorrhage(P=0.016) were predicative factors for postoperative EVD caused by acute hydrocephalus (Table 2).

In multivariate analysis, anterior invasion (OR=24.71), and postoperative hemorrhage (OR=43.47) were independent risk factors of postoperative EVD due to acute hydrocephalus.(Table 3)

Predictors of a postoperative VP-shunt

Eleven (11.3%) of all patients received a VP-shunt postoperatively, including two (2.1%) patients with a prophylactic EVD. The mean implantation time was 62.4 days (range, 14-191 days). There were five patients with obstructive hydrocephalus, four patients with communicative hydrocephalus, and two patients with isolated hydrocephalus.

In univariate analysis, age (*P* =0.003) , tumor size(*P* =0.004), Preoperative hydrocephalus (*P* =0.010), Resection degree (*P* =0.001), Postoperative acute hydrocephalus (*P* =0.049) and histology (*P* =0.003) were predictive factors for a post-resection VP-shunt (Table 4).

In multivariate analysis, only malignent tumor (OR=535.4) was an independent risk factor for post-resection VP-shunt (Table5).

Two patients with tumors located at the occipital angle of the lateral ventricle received a VP-shunt for post-resection isolated hydrocephalus. It was difficult to achieve complete intraoperative resection for the patient with pathological finding of glioblastoma identified at obstructive hydrocephalus pre-resection. Indeed, postoperative MRI revealed that the obstruction was not optimally removed because of the occupying effect and adhesion of the residual tumor. Because this patient continued to show intracranial hypertension, a VP-shunt was inserted. The second patient showed a meningioma with complete intraoperative resection. However, postoperative MRI showed obstruction caused by cerebral tissue adhesion accompanied by intracranial hypertension (Figure 3).

Declarations

Funding:

This work was supported by the Technical Innovation Special Task of Hubei Province of China (grant number 2018ACA139).

Conflicts of interest:

Chengda Zhang Ph.D. has nothing to disclose, Lingli Ge Ph.D. has nothing to disclose, Tingbao Zhang has nothing to disclose,, Zhengwei Li Ph.D. has nothing to disclose, Jincao Chen Prof., Ph.D., MD has nothing to disclose. The authors disclosed receipt of financial support for the research, authorship, and/or publication of this article.

Acknowledgments:

We thank Liwen Bianji (Edanz) (www.liwenbianji.cn/), for editing the English text of a draft of this manuscript.

Discussion

There is no current consensus on the optimal placement of EVD during LVT resection surgery. Placement of a prophylactic EVD is used to drain residual hematoma clots and bloody CSF, as well as to monitor and regulate intracranial pressure. Drainage placement can also prevent intracranial hypertension caused by acute hydrocephalus. Intraoperative EVD placement is most convenient for surgeons because the tube can be placed through the surgical channel. By contrast, for patients without prophylactic EVD who develop acute hydrocephalus after resection, the ventricular puncture site for EVD placement is selected in the emergency unit, which increases the risks of brain injury and other morbidities. Nevertheless, there are still risks of intraoperative EVD placement, including intracranial infection, increased risk of CSF leakage, and potential risk of excessive drainage. The aim of the present study was to identify patients at high-risk of acute hydrocephalus after LVT surgery for guidance of prophylactic EVD placement and to analyse the risk factors for post-resection VP-shunt placement.

To the best of our knowledge ,this regression analysis is the first to identify the characteristics of tumor location and other risk factors for hydrocephalus after LVT resection. We found that tumor invasion of the anterior part of the ventricle was an independent risk factor for postoperative EVD caused by acute symptomatic hydrocephalus. Deling et al. reported that hydrocephalus tends to develop after an LVT resection in which the tumor basement is located at the lateral ventricular wall, dorsal thalamus, choroid plexus,or third ventricle (near the foramen of Monro)(6), although statistical confirmation was not performed. Anatomically, the posterior internal choroid artery expands radially through the foramen of Monro and is the main blood supply vessel of the anterior part of the ventricle(21). Dring resection of tumors located in or invading the anterior part of the lateral ventricle, damage to these branching vessels may increase brain tissue swelling around the midbrain aqueduct after surgery, thereby narrowing the CSF pathway. For tumors invading the anterior ventricle wall or the aqueduct of the lateral ventricle, postoperative tissue adhesion may cause obstruction(22). Ktari, O et al. reported that postoperative obstructive hydrocephalus can be caused by displacement of intraventricular hemostatic materials and the inflammatory reaction associated with Gelfoam residue, with a surrounding marked giant cell reaction with underlying fibrosis, thrombosis of small superficial vessels, and reactive microglial(14).

In the present study, postoperative hemorrhage was also an independent risk factor for postoperative EVD caused by acute symptomatic hydrocephalus. Postoperative hemorrhage is a serious complication of LVT surgery. which typically manifests as intraventricular hemorrhage, while approximately 50% of intraventricular hemorrhage patients develop hydrocephalus(3, 11). Importantly, blood can stimulates the production of CSF(22), while the mass effect of the hematoma can obstruct the CSF pathway and cause symptoms of intracranial hypertension, which requires emergency CSF drainage(4, 9).

We found that incomplete resection was not a risk factor for postoperative EVD. Clinically, complete tumor resection is the main surgical goal. However, some LVTs are difficult to completely resect because of their extensive blood supply, unclear boundaries, or tight adhesion with normal brain tissue. To protect normal brain tissue and blood vessels and avoid severe postoperative intracranial edema and intracranial hypertension, our typical surgical goal is to achieve decompression and improve CSF circulation(18). Although residual tumors are a cause of recurrence, slow-growing tumors do not generally cause acute intraranial hypertension. For patients with incomplete resection, regular follow-up and review are required. If necessary, a secondary surgery or VP-shunt placement can be performed.

In the present study, presence of a malignant tumor was the only independent risk factor for VP-shunt placement after LVT surgery. Of the eleven patients with a VP-shunt, ten had a malignant tumor. For patients with subtentorial ventricle tumors, pediatric patients have a higher incidence of malignant tumors (e.g., medulloblastoma) and a higher rate of post-resection hydrocephalus(1, 13, 15, 24). The types and corresponding basements of supratentorial LVTs tend to differ with age. For example, choroid plexus papilloma, ependymoma, and central neurocytoma mainly occur in pediatric and juvenile people, and are mostly benign. By contrast, meningiomas and gliomas are most common in adults. Malignant tumors may impair CSF absorption because of leptomeningeal metastases at the subarachnoid level and the high CSF protein content produced by disseminated tumor cells(2, 17, 20). The high invasiveness of malignant tumors makes them difficult to resect. Thus, they can rapidly relapse after surgery to produce a mass effect and cause obstructive hydrocephalus. Interestingly, patients with radiation-induced brain atrophy can exhibit mildly elevated CSF pressure because of impaired CSF flow and reduced reabsorption caused by fibrosis of the arachnoid granulations(23). A VP-shunt is an alternative treatment for recurrent malignant LVT with symptomatic hydrocephalus.

In the present study, two patients with LVTs located at the occipital angle of the lateral ventricle developed isolated hydrocephalus after resection- one patient had a glioblastoma that was difficult to completely resect. while the other patient with complete resection showed brain tissue still adherence and postoperative obstruction. Ma et al. reported that excessive CSF loss by ventricular drainage can cause intracranial hemorrhage and ventricular wall adhesion, increasing the risk of localized hydrocephalus(18). However, the meningioma patient in that study did not receive EVD during surgery. Based on preoperative and postoperative MRI findings, we considered that this was related to the ventricle morphology around the tumor. The tumor with a large preoperative volume expanded the local ventricle and surrounding brain tissues, while the ventricular opening around the tumor was relatively narrow. After removal of the mass effect caused by the tumor, the surrounding brain tissue collapsed. The wide basement of the tumor resulted in a large surgical area in the ventricle, which aggravated postoperative peritumor brain tissue edema, leading to compression and adhesion of the narrow part of the ventricle and development of isolated hydrocephalus. For such wrapped tumors, we suggest timely postoperative imaging examination and enhanced dehydration treatment. We also recommend that the distal end of the shunt tube be placed across the ventricle stenosis, with particular attention paid to postoperative management of EVD to maintain ideal intracranial pressure.

Limitation

There are some limitations to our study. First, because our postoperative follow-up time varied from 3 months to 6 years, it remains unclear whether patients with a short follow-up time would develop hydrocephalus. This may have caused bias in our results. Second, because ETV was only performed in few patients with LVT in our center, evaluation of the utility of ETV was limited. Finally, there are differences in surgical procedures and perioperative management between different medical centers, which may influence our statistical findings. Further prospective studies with larger samples are required to confirm our findings.

Conclusion

Anterior invasion of LVT and postoperative hemorrhage play a critical role in development of post-resection acute hydrocephalus. Intraoperative placement of EVD and proper management of intracranial pressure are recommended for tumors invading the anterior part of the lateral ventricle. Patients with malignant LVTs were more likely to receive a post-resection VP-shunt. Tumors wrapped by the ventricles are more likely to develop isolated hydrocephalus after surgery. These findings may help in identifying patients at risk of developing hydrocephalus after LVT surgery and the preoperative communication.

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Tables

Table 1. Location and pathological characters of LVTs with postoperative CSF drainage

	Number	Postoperative EVD		Postoperative VP-shunt	
		Anterior invasion	No anterior invasion	Anterior invasion	No anterior invasion
Meningoma	32 （33.0%）		2（40.0%）		1（25.0%）
Central neurocytoma	21 （21.6%）	1（20.0%）	1（20.0%）		3（75.0%）
Glioma	18 （18.6%）	3（60.0%）	2（40.0%）	6（85.7%）	
Ependymoma	11 （11.3%）				
Choroid plexus papilloma	5（5.2%）	1（20.0%）		1（14.3%）	
Cavernous angioma	3（3.1%）				
Germinoma	2（2.1%）				
Other	5（5.2%）				
Total	97	5	5	7	4

EVD, external ventricular drainage; VP, ventriculoperitonea

Table 2: Summary of the factors with postoperative EVD

	Posotoperative EVD		P value
	Yes	No	
Sex			0.917
Male	5(7.6%)	29(43.9%)	
Female	5(7.6%)	27(40.9%)	
Age(year)	46.0±13.7	45.1±13.1	0.847
Tumor size(mm)	38.1±26.8	32.4±14.4	0.321
Tumor location			0.039
Anterior invasion	5(7.6%)	11(16.6%)	
No anterior invasion	5(7.6%)	45(68.2%)	
Postoperative hemorrhage			0.016
Yes	5(7.6%)	9(13.6%)	
No	5(7.6%)	47(71.2%)	
Preoperative hydrocephalus			0.052
Yes	6(9.1%)	16(24.2%)	
No	4(6.1%)	40(60.6%)	
Resection degree			0.013
Complete resection	7(83.0%)	53(97.8%)	
Incomplete resection	3(17.0%)	3(2.2%)	
Histology			
Benign	2(3.0%)	29(43.9%)	0.064
Malignant	8(12.1%)	27(40.9%)	

EVD, external ventricular drainage

Table 3. Multivariate analysis of the association between postoperative EVD and factors

	Multivariate analysis	
	P value	OR(95%CI)
Anterior invasion	0.020	24.71(1.67-366.4)
Postoperative rebleeding	0.004	43.47(3.23-584.74)
Incomplete resection	0.513	

Nagelkerke R2 = 0.533

Table 4: Summary of the factors with postoperative VP-shunt

	Posotoperative VP-shunt		P value
	Yes	No	
Sex			0.394
Male	4(4.1%)	43(44.3%)	
Female	7(7.2%)	43(44.3%)	
Age(year)	30.4±10.3	45.1±13.2	0.003
Tumor size(mm)	49.7±18.4	34.2±3.1	0.004
Tumor location			0.331
Anterior invasion	2(2.1%)	28(28.9%)	
No anterior invasion	9(9.3%)	58(59.8%)	
Postoperative hemorrhage			0.631
Yes	3(3.1%)	18(18.8%)	
No	8(8.3%)	68(70.8%)	
Preoperative hydrocephalus			0.010
Yes	9(9.3%)	35(36.1%)	
No	2(2.1%)	51(52.6%)	
Resection degree			0.001
Complete resection	5(5.2%)	8(8.2%)	
Incomplete resection	6(6.2%)	78(80.4%)	
Prophylactic EVD			0.308
Yes	5(5.2%)	26(26.8%)	
No	6(6.2%)	60(61.2%)	
Postoperative acute hydrocephalus			0..049
Yes	3(3.1%)	7(7.2%)	
No	8(8.2%)	79(81.4%)	
Histology			
Benign	1(1.0%)	37(38.1%)	0.003
Malignant	10(10.3%)	49(50.5%)	

EVD, external ventricular drainage; VP, ventriculoperitonea

Table 5. Multivariate analysis of the association between postoperative VP-shunt and factors

	Multivariate analysis	
	P value	OR(95%CI)
Age（year）	0.161	
Tumor size（mm）	0.070	
Preoperative hydrocephalus	0.973	
Incomplete resection	0.291	
Postoperative acute hydrocephalus	0.425	
Malignant	0.004	535.4(7.2-39687.1)

Nagelkerke R2 = 0.667

VP, ventriculoperitonea

Figures

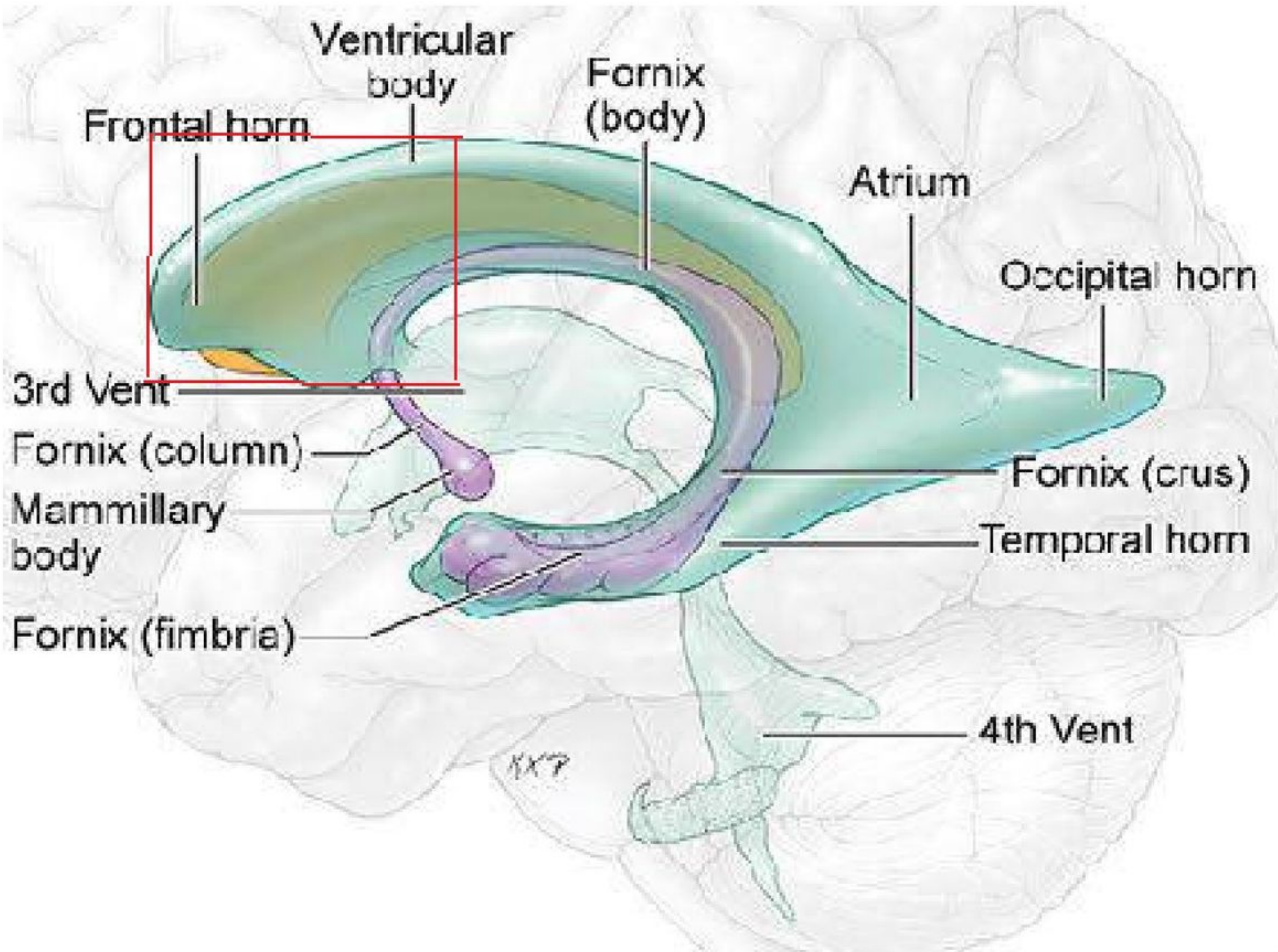

Figure 1

The red box shows the anterior part of lateral ventricle.

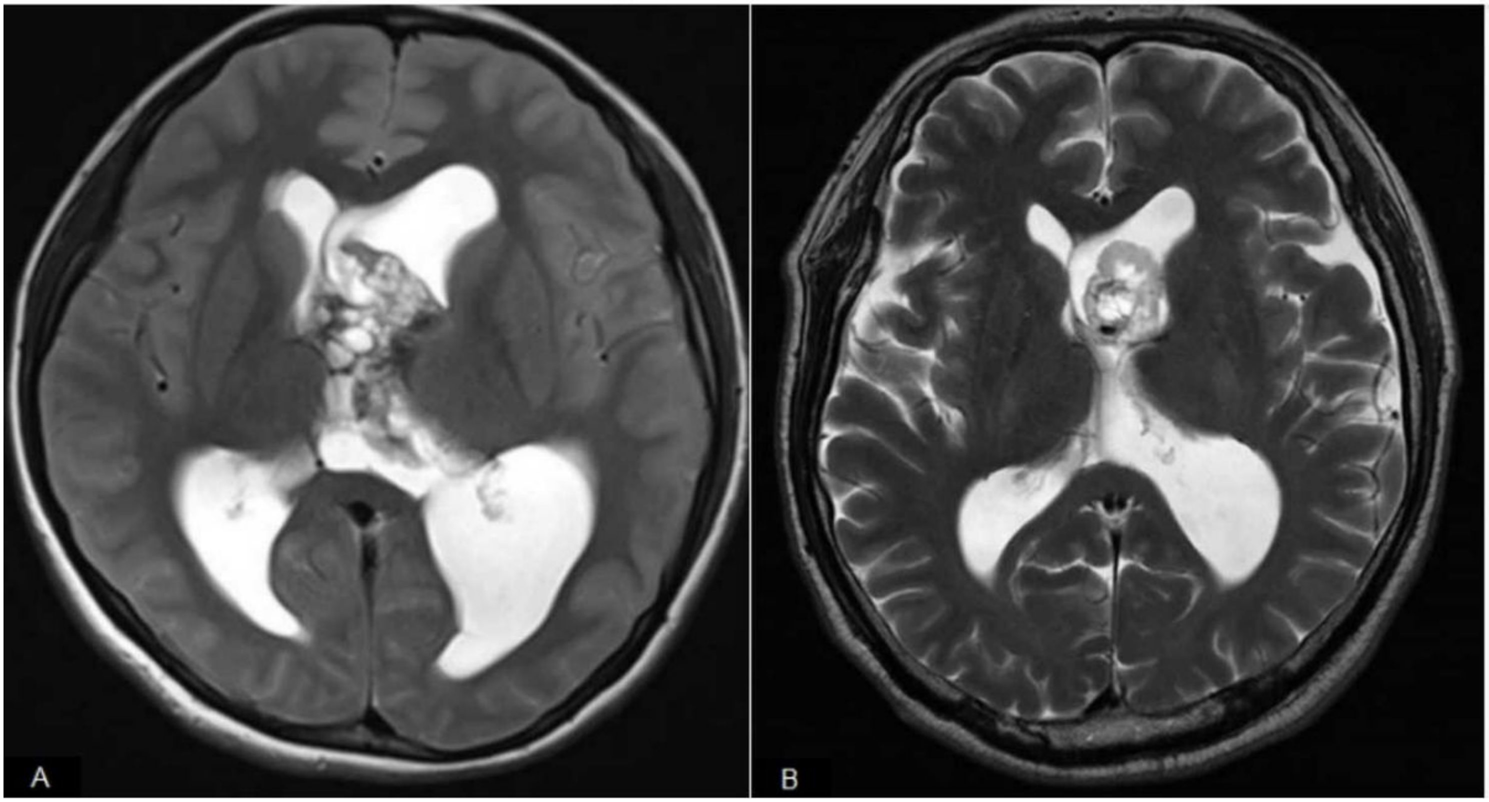

Figure 2

(A and B) The axial T2-image shows the anterior invasion lateral ventricular tumor.

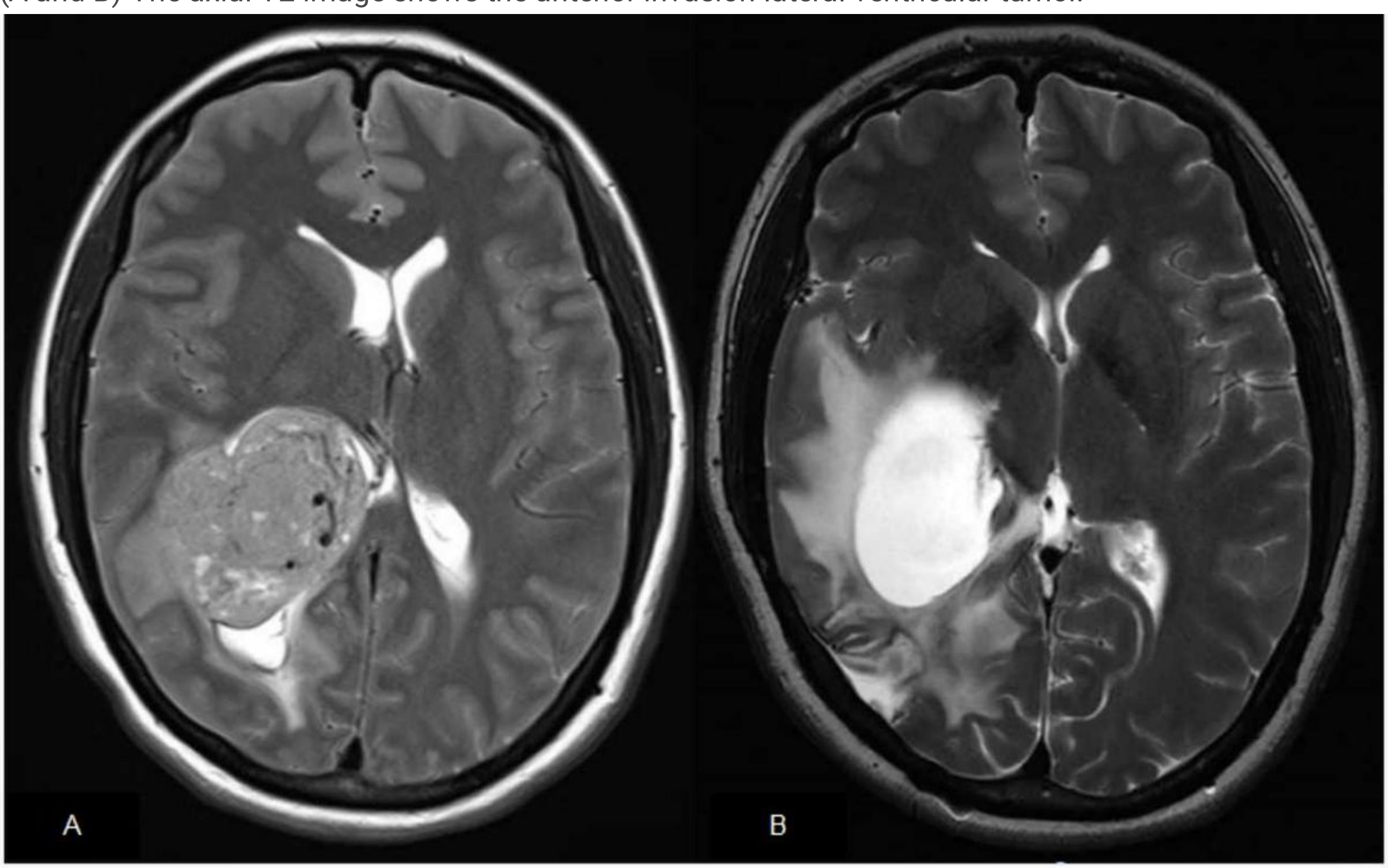

Figure 3

The pre-resection axial T2-image shows the right lateral ventricular tumor, B. The post-resection axial T2-image shows the isolated hydrocephalus.