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Original Article

A classification of lesions around interventricular foramen and its clinical value

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Abstract: Objectives: Lesions around interventricular foramen are difficult to remove for their important adjacent structures. We classify these tumors according their location on Magnetic Resonance Image (MRI) to help us resect these lesions. Methods: Thirty-two tumors around the interventricular foramen were studied according their location and anatomic relations in MRI. Results: Tumors around interventricular foramen were classified into three types. The first one mainly locates in lateral ventricle and the second one growth both in lateral ventricle, interventricular foramen and third ventricle, while the third one mainly in third ventricle. Different surgical approaches were adopted according their classification and the patients recovered well. Conclusion: This classification can help us to chose the surgical approach for these tumors.

Keywords: Interventricular foramen, tumor, classification, surgical approach, magnetic resonance imaging

Introduction

Interventricular foramen is the only passway connecting the lateral ventricle and third ventricle, meanwhile, it compose of fornix, anterior pole of thalamus and choroid plexus which relevant to memory and hydrocephalus. Furthermore, the size of the foramen is less than 1 centimeter and the operating space is very narrow and small, so it is difficult to remove the mass and protect these important structures at the same time.

Literatures show that lesions originated from the area of interventricular foramen are rare and mostly case reports [1-5], most of them accompany with hydrocephalus [2, 4, 6]. These tumors may happened in lateral ventricle or third ventricle or in both, and the approaches to these area are totally different. So it is very necessary to choose an appropriate surgical approach for them and it is one of the key point to success of operation. We classify these tumors into three types by their location in Magnetic Resonance Image (MRI) and the result show that it is really help us to choose the surgical approaches for these lesions.

Materials and methods

Study population

Thirty-two cases with tumors around interventricular foramen were treated in our department from 2008 to 2014. These patients ranged from 8 to 62 years with an average age of 39. All cases were confirmed by pathology, including 12 astrocytoma, 6 glioblastoma multiform, 4 ependymoma, 2 subependymal giant cell astrocytomas (SGCAs), 3 meningioma, 2 cavernous hemangioma, 2 lymphoma and 1 teratoma.

Symptoms of intracranial hypertension like headache, nausea, and vomiting were detected in 30 cases. Visual impairment occurred in 6 cases, memory decline in 5 cases, and sensory dysfunction on one side of the limb in 5 cases. Epilepsy was found as the initial symptom in 2 case, which was characterized by complex generalized seizure.

Neuroimaging of interventricular foramen

The interventricular foramen is a small structure at the deep inside of ventricular system, which locate between the lateral ventricle and

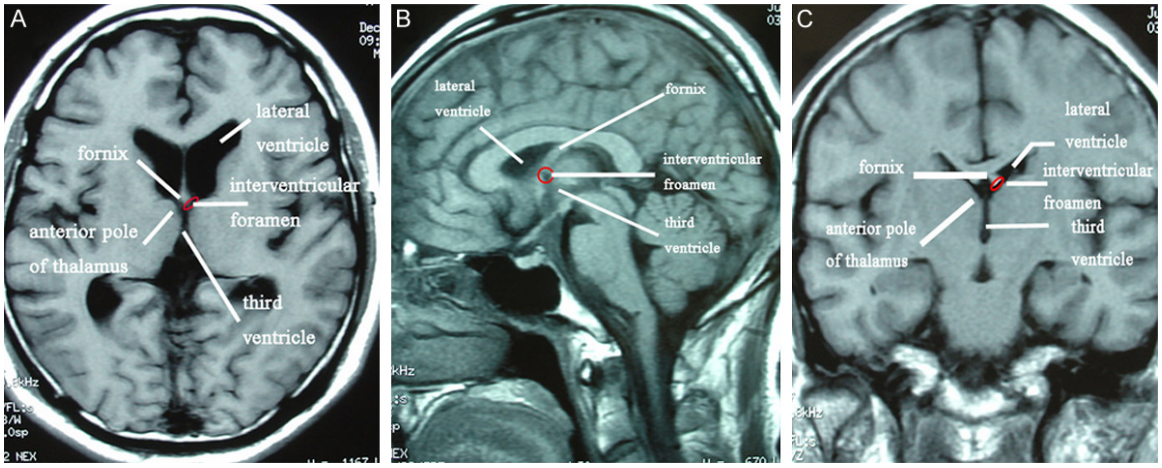

Figure 1. The normal interventricular foramen on MRI. A-C.

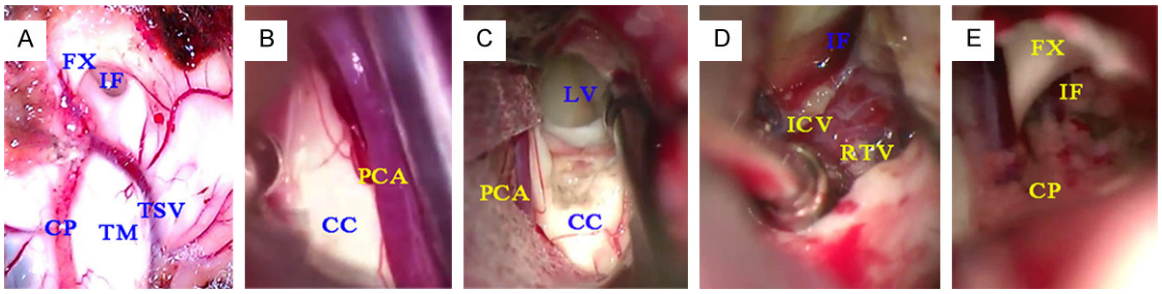

Figure 2. Expose the interventricular foramen and choroid fissure during operation. A. The interventricular foramen (IF), choroid plexus (CP), and thalamostriate vein (TMV) as ventricular landmarks during transcortical transventricular approach. B. The corpus callosum (CC), and the pericallosal arteries (PCA) are identified during interhemispheric transcallosal transventricular approach. C. After dissecting corpus callosum, then the lateral ventricle is opened. D. Some important structures such as internal cerebral veins (ICV) and the top of third ventricle (TTV) can be expose during dissecting choroid fissure. E. The interventricular foramen's view during the interhemispheric transcallosal interforniceal approach.

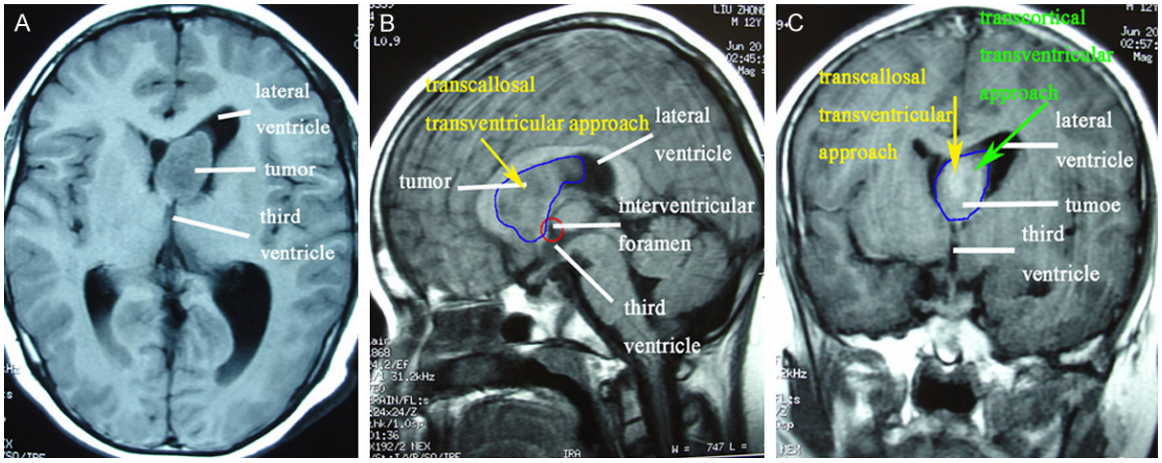

Figure 3. First type tumors around interventricular foramen. A. Axial image shows the tumor mainly locate in left lateral ventricle. B. Sagittal image shows the tumor (blue solid line) locate in lateral ventricle but not enter into the third ventricle. The interventricular foramen (red solid line) and fornix are squeezed. C. The relationship of tumor and interventricular foramen on coronal image shows. Both transcortical transventricular approach (green arrow) and interhemispheric transcallosal transventricular approach (yellow arrow) can be used in first type tumors.

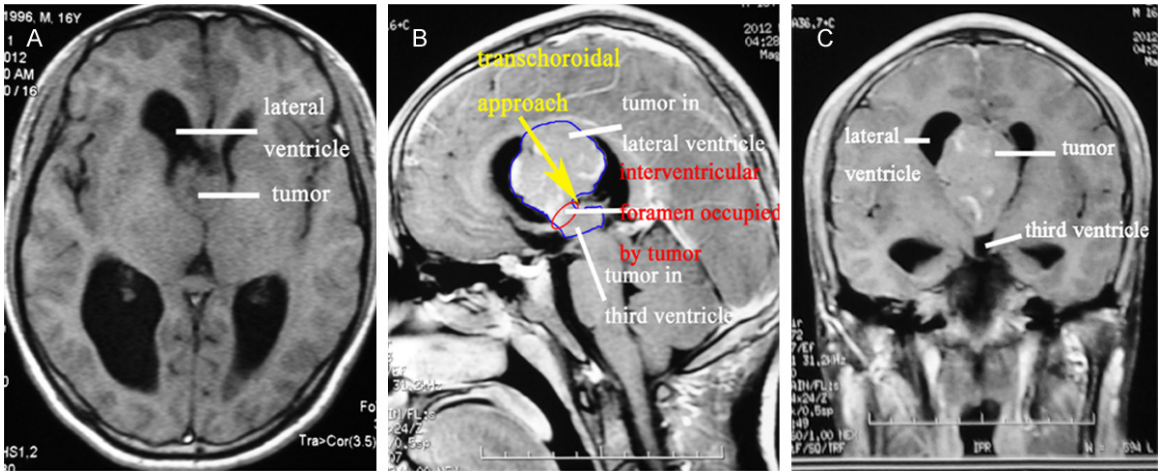

Figure 4. Second type tumors around interventricular foramen. A. Axial image shows the tumor locate in lateral ventricle and interventricular foramen. B. Sagittal image shows the tumor (blue solid line) locate in lateral ventricle and third ventricle, the interventricular foramen (red solid line) is occupied by tumor and shape a gourd structure. The operation need to open the interventricular foramen and the roof of the third ventricle which the transchoroidal approach (yellow arrow) is appropriated. C. Coronal image of second type tumor.

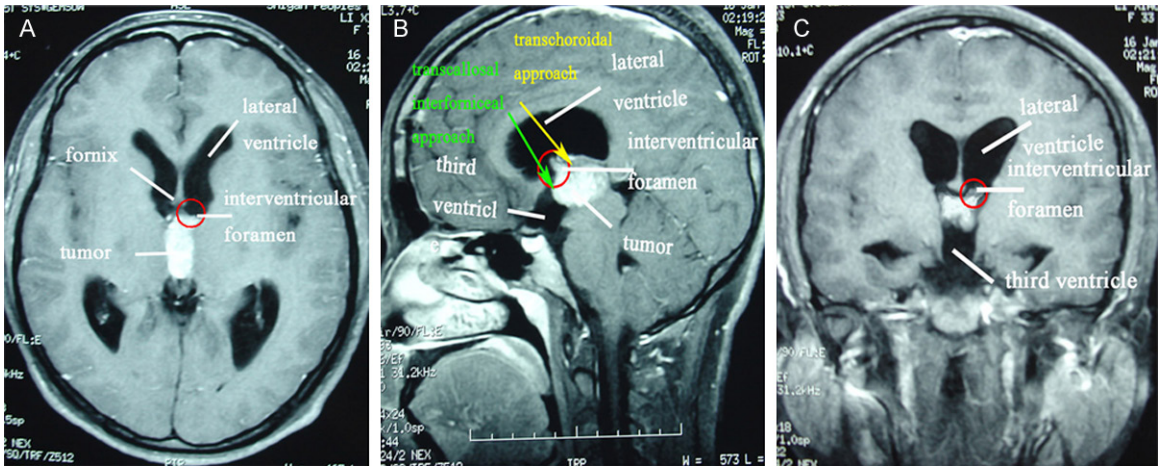

Figure 5. Third type tumors around interventricular foramen. A. Axial image shows the tumor mainly locate in third ventricle. B. Sagittal image shows the tumor is mainly located in posterior part of interventricular foramen and the third ventricle. The transcallosal interforniceal approach (green arrow) and the transchoroidal approach (yellow arrow) can be used for this kind of tumors. C. Coronal image of third type tumor.

third ventricle, between the fornix and the anterior pole of the thalamus (**Figure 1A-C**). In the axial image, we can see that the anterolateral, posterolateral, posteromedial and anteromedial structures are the front lateral ventricle, the anterior pole of the thalamus, the third ventricle, and fornix respectively (**Figure 1A**). In the sagittal image, we can see that the above, below and rear structures are the fornix, the third ventricle, the anterior pole of the thalamus respectively (**Figure 1B**). In the coronal image, we can see that the anterolateral, posterolateral, posteromedial and anteromedial structures are the front lateral ventricle, the anterior pole of the thalamus, the third ventricle, and fornix respectively, which is the same as the axial image (**Figure 1C**). For tumors around the interventricular foramen, we classified them by their location, shape and the relationship with interventricular foramen regardless their histology.

Axial, sagittal and coronal image shows the interventricular foramen locate between lateral

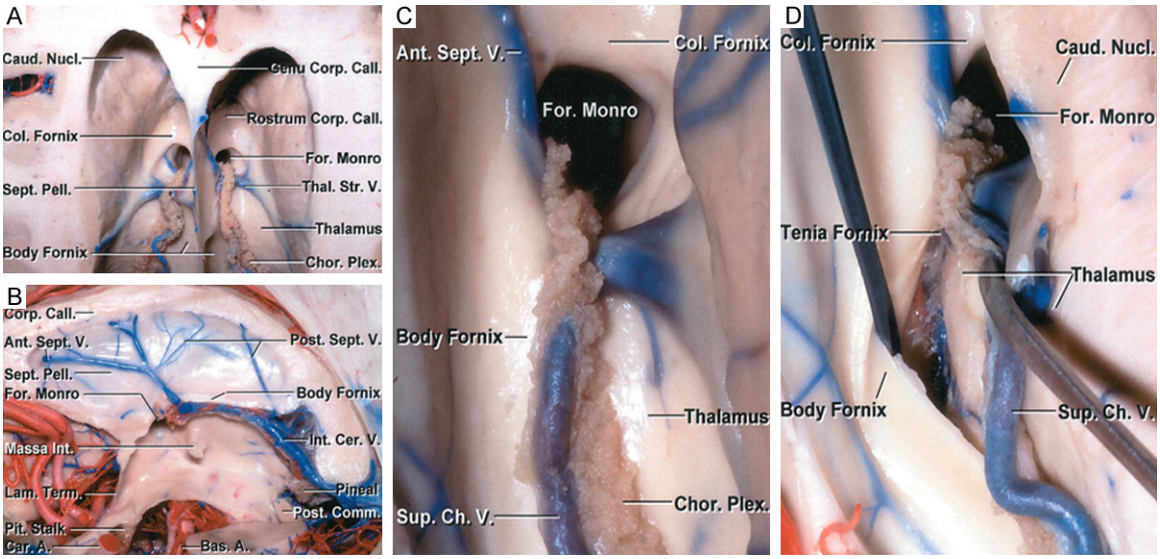

Figure 6. The composition and the adjacent structures of the interventricular foramen and the transchoroidal approach. A. Superior view of the lateral ventricles and interventricular foramen. B. Midsagittal views of the third ventricle and interventricular foramen. The rear of the interventricular foramen is roof of the third ventricle which contain the choroid plexus and the thalamostriate vein. C. Enlarged view of the foramen of Monro. The choroid plexus is attached medially by the tenia fornix to the body of the fornix and laterally by the tenia thalami to the thalamus. D. The transchoroidal exposure is begun by dividing the tenia fornix that attaches the choroid plexus to the margin of the fornix. (Rhoton AL Jr: The lateral and third ventricles. Neurosurgery 51 (4 Suppl): S207-S271, 2002).

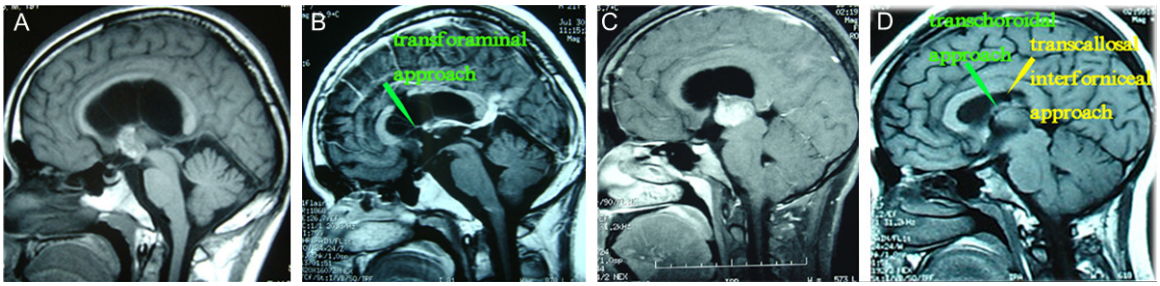

Figure 7. Subtype of the third type tumors and its surgical approaches. A. Tumors in the anterior part of the third ventricle is the first subtype. B. Transforaminal approach can be used and post-operation MRI shows the tumor totally removed. C. Tumors in the posterior part of the third ventricle is the second subtype. D. Transcallosal interforniceal approach and the transchoroidal approach can both be used and post-operation MRI shows the tumor totally removed.

ventricle and third ventricle. Red line circle is the interventricular foramen.

Surgical approaches

We chose surgical approaches according to the principle minimal invasive and they have some common features which including making full use of the nature space and fissure in the brain, maximally protect normal structures and so on.

The transcortical transventricular approach need a cortical section on the middle frontal gyrus [7, 8]. After entering into the lateral ventricle, tumor exposed and internal debulking is needed. When the tumor removed, the normal ventricular landmarks such as the interventricular foramen, choroid plexus, and thalamostriate vein can be identified (**Figure 2A**). The interhemispheric transcallosal transventricular approach need to separate the dura from the brain to the sagittal sinus [9]. After access to the interhemispheric fissure, the cingulate gyrus and sulcus, the corpus callosum, and the pericallosal arteries are identified (**Figure 2B**). A 1.5-2 cm long incision made through the cor-

pus callosum and then the roof of lateral ventricle is opened (**Figure 2C**).

The transchoroidal approach can expose the lateral ventricle, the interventricular foramen and the third ventricle at the same time [10-12]. This approach can be used for the second and the third type of the tumors, but the procedures are different. For the second type tumors, we need to reduce the size of the mass and get operation space first and then to observe the landmark of the ventricular system. While for the third type of tumors, we can see these structures easily. After gently lifting the choroid plexus and opening the taenia fornicis, the velum interpositum is entered and the internal cerebral veins and the medial posterior choroidal arteries are visualized (**Figure 2D**). These vessels should be retracted laterally until the inferior membrane of the tela choroidea and the choroid plexus of the third ventricle be divided in the midline. Then the third ventricle is opened and whole tumor is visualized.

The interhemispheric transcallosal interforniceal approach has the same route as the interhemispheric transcallosal approach before separating the septum pellucidum [13-17]. After incision of the corpus callosum, it need to separate the septum pellucidum strictly following the midline to the fornix and entering the third ventricle. Transforaminal approach is also has the same step with interhemispheric transcallosal transventricular approach before entering lateral ventricle. Once interventricular foramen is exposed, then the tumor in third ventricle can be remove through the space of the foramen (**Figure 2E**).

Results

Classification from MRI

We classified these tumors into three types according their location and shape on MRI. The first type of tumors mainly locates in lateral ventricle and the interventricular foramen is involved. We named them "Lateral Ventricular Type Tumors" (**Figure 3A-C**). The second type tumors locate in lateral ventricle and extend into the third ventricle through the interventricular foramen. We named this kind of tumor as "Gourd-like Type Tumors" (**Figure 4A-C**). The third type of tumors mainly locate in the third ventricle and the interventricular foramen is involved and we named them as "Third Ventricular Type Tumors" (**Figure 5A-C**). There are 16 cases in first type and we chose transcortical transventricular approach or interhemispheric transcallosal transventricular approach. The second type tumors included 7 cases and the transchoroidal approach was used. While, there are 9 cases belong to third group and interhemispheric transcallosal transforaminal approach, transcallosal interforniceal approach or transchoroidal approach were adopted.

Clinical outcome

In 32 patients, 26 tumors were totally removed, 4 were subtotally removed, and 2 were partly removed. The total resection rate is 81.25%. The clinical outcome is good. According to the Glasgow Outcome Score (GOS) at discharge, 22 patients recovered well (GOS=5), and the clinical symptoms of intracranial hypertension disappeared, while other symptoms (visual impairment, epilepsy) improved. As shown in the image, the hydrocephalus decreased after the operation. The moderate disability (GOS=4), mainly slight hemiplegia, founded in 4 patients. Two patients suffered severe disability (GOS=3) and needed help for daily living. Another two patients suffered vegetative state (GOS=2) and his family gave up at last. Unfortunately, two patients died (GOS=1) due to the damage of the deep vein around the interventricular foramen.

Discussion

The interventricular foramen is also known as the foramen of Monro which was first described by Alexander Monro in 1783 and 1797 [18, 19]. However, many authors thought the term foramen of Monro was a misnomer and should be replaced by the term of interventricular foramen because Monro misinterpreted the nature of communication between the third and lateral ventricles [18, 19]. The interventricular foramen is composed of the fornix, the anterior pole of thalamus and the choroid plexus. The fornix constitutes the upper and front portion, the anterior pole of thalamus constitutes the inferior and lateral portion, and the choroid plexus connects the fornix to the anterior thalamus (**Figure 6A-C**). The fornix and anterior thalamus are the main structures of the interventricular foramen. Fornix damage can cause memory dysfunction while injury to the anterior

thalamus can also lead to memory and conscious impairment.

The adjacent structures include the thalamostriate vein, the anterior septal veins, the anterior caudate vein, the internal cerebral vein, the superior choroidal vein, the internal capsule, the septum pellucidum, frontal horn and the body of lateral ventricle, anterior and roof of the third ventricle (**Figure 6A-C**). The injury of thalamostriate vein or the internal cerebral vein may cause serious consequences including hemiplegia, coma and even to death. Damage of the anterior part of the third ventricle may cause water and salt metabolism disorder symptoms. In the lateral of the interventricular foramen are thalamus and the internal capsule, the injury of which can lead to coma and hemiplegia in patients.

The normal size of the interventricular foramen is just about several millimeters and there are so many important structures nearby, therefore, the operation around this area is very difficult and still a challenge for neurosurgeon.

Lesions around the interventricular foramen are not common. Several types of tumors in this area, including astrocytoma, subependymoma, neurocytoma, ependymoma, oligodendroglioma, glioblastoma multiforme, choroid plexus papilloma, cavernous hemangiomas, germinoma, colloid cyst and meningioma, have been described [1, 2, 4, 6, 20-23]. There is no classification for these tumors and we classify them into three types which can help us to choose the surgical approach. For the first type tumors, due to these tumors mainly locate in lateral ventricle (**Figure 3A-C**), and most of them in the front horn of the lateral ventricle, therefore, choosing surgical approach should be emphatically exposed the frontal lateral ventricle. Both the front transcortical transventricular approach and interhemispheric transcallosal transventricular approach can expose frontal lateral ventricle effectively. So, it is enough for us to choose any one of these approach for the first type of tumors. For those cases when the interventricular foramen is obstructed totally, some assistant approaches such as transchoroidal approach is needed. Fortunately, 13 cases of our first type of tumors are partly obstructed in the foramen and no any other approach needed. The choosing of the which one of these two approaches is largely dependent on the surgeon's experience. In general, the transcortical approach has the advantages of (1) easy access to large tumors, and (2) the absence of any bridging vein injury and any incision of corpus callosum [24-26]. In contrast, the transcallosal approach has the advantages of (1) easy access to both lateral ventricles, (2) the absence of a cortical incision, and (3) easier performance in the setting of normal ventricular size[24]. For us, the transcallosal approach is adopted for the big tumor which the midline structure shift and the contralateral ventricle compressed while the transcortical approach for the small one.

The key point of choosing approaches for the second type tumors is to expose lateral ventricle, interventricular foramen and third ventricle at the same time. For the whole view of the mass and the total resection of the tumor, it is needed to open the interventricular foramen. Those approaches need cutting off the fornix to enlarge the foramen, which will lead to memory impair after operation and had been abandoned almost. Pushing the anterior of the thalamus to enlarge the interventricular foramen will result the coma to patient and no neurosurgeon had attempt. So, there is only one way to enlarge the interventricular foramen which is the opening the choroidal fissure from the rear of the foramen. An understanding of the choroidal fissure is fundamental for use of the transchoroidal approach (**Figure 6D**). The choroidal fissure is a natural cleft between the thalamus and the fornix in the lateral ventricle [27]. The transchoroidal approach begins with the opening of the taenia fornicis and the superior membrane of the tela choroidea, and then dissecting the vascular layer medially to the internal cerebral vein. After the inferior membrane of the tela choroidea and the choroid plexus of the third ventricle have been opened in the midline, the cavity of the third ventricle can be completely seen. Then the posterior limit of the interventricular foramen has been expanded through the choroidal fissure, without sacrificing any neural or even vascular structures. If additional space is needed for surgery, the only structure that restricts further expansion of the foramen is the anterior septal vein, which can be sacrificed if necessary (**Figure 6D**).

Tumors in the third ventricle are difficult to expose for its long distance to reach. Various approaches to third ventricle, including trans-

cortical-transforaminal approach, transcallosal interforniceal approach, transchoroidal approach, transcallosal-subchoroidal trans-velum interpositum approach, subfrontal trans-lamina terminalis approach, pterional approach have been reported [28]. We use transcortical-transforaminal approach, transcallosal interforniceal approach and the transchoroidal approach for the third type tumors because these approaches can expose third ventricular and interventricular foramen at the same time. But which one will be used is largely depend on the tumor's location on MRI. From the sagittal image, we can classify this type tumors into two subtypes (**Figure 7A-D**). Tumors in the anterior part of the third ventricle is the first subtype and interhemispheric transcallosal transforaminal approach will be used, because this kind of tumor needn't to enlarge the interventricular foramen (**Figure 7A**). While tumors in the posterior part of the third ventricle is the second subtype, which transcallosal interforniceal approach or transchoroidal approach will be used, because the roof of the third ventricle or the interventricular foramen need to open (**Figure 7B**).

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Disclosure of conflict of interest

None.

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