Intracranial aneurysms mimicking third ventricular masses: case series and systematic review

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ABSTRACT
Objective: Intracranial aneurysms presenting as third ventricular and adjoining part masses are rare and are always associated with obstructive hydrocephalus. It is vital to provide precise diagnostics and apt treatment for such patients since endovascular or microsurgical operations remain challenging. This study aimed to discuss differential diagnosis tactics based on the cases we followed and the current literature on intracranial aneurysms mimicking third ventricular masses.

Methods: We followed a case series of intracranial aneurysms presenting as third ventricular masses. Literature reports related to aneurysms adjoining the third ventricle since 1979 were systematically reviewed and summarized.

Results: Twenty-seven cases of this disease were collected. A total of 92.6% of cases developed hydrocephalus. Six cases were reported as third ventricular tumors in primary radiologic reports, and misdiagnosis hindered subsequent clinical decisions. We found a significant correlation between thrombosis and misdiagnosis, as well as between misdiagnosis and craniotomy rate. There are also false negative angiography reports for aneurysms from our cases and literature review. Strategies for the diagnosis and treatment of these aneurysms have changed over time. The uniqueness of our cases sheds light on the use of CT angiography, which has proven to be an appropriate test for diagnosis and reexamination but was not widely applied in previous reports. VW-MRI may be useful to assess rupture risk. Distinct treatment strategies show no significant difference in prognosis.

Conclusions: Thrombosed aneurysms should be considered as a differential diagnosis in patients with third ventricular masses. Application of CTA and VW-MRI can be beneficial. Aneurysm coil occlusion might be a favorable treatment for cases with mass effects. Further studies should be conducted to confirm our observations.

1. Introduction

Third ventricular masses, including various tumors, such as germ cell tumors, glial cell tumors, craniopharyngiomas [1], meningioma, epidermomas, choroid plexus tumors [2, 3, 4], epidermoid cysts [5, 6], and various vascular malformations [7], can cause obstruction of cerebral spinal fluid (CSF) flow and result in hydrocephalus. Identifying the pathological histology of this area is of great clinical importance, especially for rare intracranial aneurysms [8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26]. These intracranial aneurysms are usually giant, sometimes with thrombogenesis inside, which makes a portion of these aneurysms resemble brain tumors on magnetic resonance imaging (MRI) and computed tomography (CT). Mass effect, thrombosis and calcification can appear in intracranial aneurysms, causing compression of important surrounding structures such as cranial nerve compression paralysis and limb paralysis to varying degrees or increased intracranial pressure due to occupation. Angiography may have false negative results because of thrombosis in aneurysms. Intracranial aneurysms can be misidentified due to atypical symptoms, which are more common in brain tumors. These factors contribute to neuroimaging error reporting, which occurs in our cases and previous studies. Craniotomy for those “tumor resections” could be dangerous when aneurysms are not considered. To avoid this unexpected intraoperative situation, preoperative examinations should be performed to detect potential aneurysms. CT is the most commonly used neuroimaging method in neurosurgical disease due to the convenience and excellent sensitivity for acute hemorrhage. Additionally, the superiority of showing calcification makes CT scans valuable in the identification of calcific aneurysm walls. MRI has high specificity in the diagnosis of large intracranial aneurysms, especially in the manifestation of aneurysm lumen and luminal

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Table 1. Baseline information of cases.

| Author          | Time  | Age/Sex | Site     | Size    | Rupture | Neuroimaging          | Hydrocephalus |
|-----------------|-------|---------|----------|---------|---------|-----------------------|---------------|
| Babu et al.     | 1979  | 52/M    | Acomm    | large   | No      | CT, DSA               | T             |
| Koga et al.     | 1983  | 65/F    | BA       | large   | No      | CT, DSA               | T             |
| Piek et al.     | 1983  | 60/F    | BA       | giant   | No      | CT, DSA               | T             |
| Bose et al.     | 1983  | 55/F    | BA       | giant   | No      | CT, DSA               | T             |
| Borrie et al.   | 1985  | 72/F    | BA       | giant   | No      | CT, DSA               | T             |
| Kishibashi et al| 1992  | 63/M    | BA       | large   | No      | CT                    | T             |
| Smith et al.    | 1994  | 60/F    | Pcomm    | giant   | Yes     | MRI, DSA              | T             |
| Koyama et al.   | 1996  | 67/F    | BA       | giant   | No      | CT, MRI, DSA          | T             |
| Hongo et al.    | 2001  | 70/F    | BA       | giant   | Yes     | CT, MRI, DSA          | T             |
| Ishihara et al. | 2002  | 72/F    | BA       | large   | No      | CT                    | T             |
| Gelal et al     | 2002  | 58/M    | BA       | giant   | No      | CT, MRI, MRA, DSA     | T             |
| Nabika et al    | 2002  | 58/M    | BA       | giant   | Yes     | CT, DSA               | T             |
| Liu JK et al    | 2005  | 55/M    | BA       | large   | No      | MRI, MRA, DSA         | T             |
| Tsutsumi et al. | 2008  | 58/M    | BA       | large   | No      | CT, MRI, MRA, DSA     | T             |
| Stachura et al. | 2008  | 82/M    | BA       | giant   | No      | CT, DSA               | T             |
| Oertel et al    | 2009  | 80/M    | BA       | giant   | No      | CT, MRI               | T             |
| Castro et al    | 2009  | 55/M    | BA       | giant   | No      | MRI                   | T             |
| Castro et al    | 2011  | 62/F    | ACA      | large   | No      | CT, MRI, DSA          | T             |
| Sato et al      | 2012  | 76/F    | BA       | giant   | No      | MRI, MRA, DSA         | T             |
| Kalousek et al  | 2020  | 62/F    | BA       | large   | No      | CT, MRI, DSA          | T             |
| Case 1          | 2020  | 14/F    | BA       | giant   | No      | CT, CTA, MRI, DSA     | T             |
| Case 2          | 2020  | 61/F    | BA       | giant   | No      | CT, CTA, MRI, DSA     | T             |
| Case 3          | 2021  | 53/M    | Acomm    | giant   | Yes     | CT, CTA, MRI, DSA     | F             |
| Case 4          | 2021  | 60/F    | BA       | giant   | No      | CT, CTA, DSA          | F             |
| Case 5          | 2021  | 67/M    | Acomm    | large   | Yes     | CT, CTA, DSA          | T             |

F/M, female/male; T/F, true/false; BA, basilar artery; Acomm, anterior communicating artery; Pcomm, posterior communicating artery; MCA, Middle Cerebral Artery; ACA anterior cerebral artery.
thrombus. Typical thrombus signals in aneurysms are mixed signals with high and low alternating layers or vortexes. In addition, irregular flowing blood vortices in the aneurysm lumen can cause blood flow artifacts in the phase code direction of MRI. These flow artifacts are favorable in diagnosing aneurysms. In addition, MRI can provide important information about the relationship between aneurysm location and surrounding structures. Digital subtraction angiography (DSA) is considered to be the gold standard for diagnosing aneurysms and is widely used in cerebrovascular diseases. There is no doubt that DSA is reliable in diagnosing intracranial aneurysms, but it is an invasive procedure that is usually not a preferred inspection method for screening. In addition, DSA may result in false-negative or imprecise results in aneurysms with thrombosis. Computed tomographic angiography (CTA) and magnetic resonance angiography (MRA) are also commonly used angiography techniques, with greater safety and convenience. To optimize neuroimaging tactics for this particular intracranial space-occupying lesion, all radiologic methods need to be assessed.

Even with detailed information of a case, how to cope with aneurysms adjoining the third ventricle remains to be determined. This may be because the change in intracranial pressure after surgery or the generally giant size of the aneurysm and the high risk of hemorrhage, aneurysm rupture, and cerebral infarction render the prognosis of the patient usually unfavorable. Aneurysm rupture during surgery is the most likely cause of death [8, 10, 11, 13, 25, 26]. The surgical approach has developed, and with a view to the history of this situation, better treatment strategies may emerge.

This study aimed to assess different neuroimaging methods in revealing aneurysms adjoining the third ventricle through our cases and a literature review, and to investigate the appropriate treatments for hydrocephalus and stabilizing aneurysms under these circumstances.

### 2. Materials and methods

#### 2.1. Case series

This case series was conducted with ethical approval from the Ethical Institutional Review Board, and informed consent was obtained from all patients. Here, we present a case series of 5 patients with aneurysms oppressing the third ventricle. All cases included were treated and diagnosed with aneurysms using various imaging techniques.
followed by our medical team during 2015–2021. Inclusion criteria were 1) aneurysms oppressing the third ventricle that were operated on by a single group of surgeons; 2) complete admission imaging and angiographic data; 3) recorded treatment modality; and 4) at least 1 imaging and clinical follow-up after treatment. The exclusion criteria were 1) hypothermic circulatory arrest used during treatment and 2) refusal to operate. Information collected included patient demographics, clinical characteristics, treatment techniques, clinical outcomes, and radiologic images. One of our cases was a anterior cerebral artery aneurysm that was not directly associated with the third ventricle (case 3), but the mass was close to the third ventricle, and the lesion also caused hydrocephalus. VW-MRI (vessel wall MRI) was conducted in this case to estimate the risk of aneurysm rupture. We believe that this case can also inform us of the proper diagnostic and surgical strategies for aneurysms adjoining the third ventricle.

2.2. Literature search strategy

Reporting of Items for Systematic Reviews and Meta-Analyses protocols [27, 28] was used as a reference. The first reported aneurysm simulating a third ventricle tumor was in 1979 by Babu and Eisen [8]. Therefore, we systematically reviewed the literature (Embase and PubMed) from 1 January 1979 to 30 November 2020. Key words and Medical Subject Headings terms used alone or in combination included “intracranial aneurysm” and “third ventricular mass” with no language restriction. The search was limited to human subjects. The reference lists of all retrieved articles were reviewed for further identification of potentially relevant studies.

2.3. Study selection

Two authors (LY, LH) independently reviewed the titles and abstracts for the selection criteria. Inclusion criteria were 1) aneurysms oppressing the third ventricle; 2) imaging and angiographic presentation before treatment; 3) recorded treatment modality; and 4) clinical results and follow-up after treatment. The exclusion criteria were 1) hypothermic circulatory arrest used during treatment and 2) technical notes, reviews, letters to the editors, commentaries and articles without an abstract. Any disagreement during article selection was resolved by discussion with the corresponding author (LQ).

2.4. Data extraction

Data were extracted from case reports, tables, and figures. Extracted data included year of publication, demographics, clinical presentation, admission radiologic characteristics, treatment modality, radiologic and clinical outcomes. Outcomes were defined as imaging reports suggesting a third ventricle tumor, aneurysm hemorrhage, occlusion, and hydrocephalus or aneurysm development.

2.5. Data analysis

Data were analyzed to estimate significant correlations between outcomes and certain characteristics (primary imaging reported a tumor, hemorrhage, occlusion, and aneurysm development) of cases using Statistical Product and Service Solutions (SPSS version R24.0.0.0). Fisher’s precision probability test and odds ratio (OR) were applied to explore the dataset.
3. Results

We aggregated our clinical and follow-up outcomes with data from a literature review for further analysis (Figure 1). The baseline information of all cases can be found in Table 1.

3.1. Case presentation

3.1.1. Case 1

A 14-year-old girl presented with headache, nausea, and blurring of vision. MRI of the sellar region revealed a $41 \times 24 \times 23$ mm solid-cystic lesion located in the suprasellar region (Figure 2A, B). Hormone tests revealed declines in adrenocorticotropic hormone (ACTH) and cortisol levels (Table 2). The lesion was considered as a craniopharyngioma in the MRI report. On CTA, the lesion located in the suprasellar region was found to be connected with the basilar artery, and the lesion was considered as a thrombosed basilar apex aneurysm, which was later confirmed by DSA (Figure 2C, D). The patient underwent craniotomy for diagnosis and CSF diversion. An injector was used to poke the mass, and arterial blood was observed in the injector, determining the mass to be a thrombosed giant aneurysm. Hormone tests after surgery (aneurysm coil occlusion) showed significant recovery in ACTH and cortisol (ACTH: 0.987 pmol/L; cortisol: 296 nmol/L). The patient recovered fairly well, and clinical and radiological follow-ups with brain CT scanning and CTA was conducted during 19 month (Figure 3A–D).

3.1.2. Case 2

A 61-year-old female suffered from headaches and limb inertia. The CT scan and MRI revealed a $25 \times 25 \times 24$ mm lesion located in the third ventricle and hydrocephalus (Figure 4A, B), estimated to be an aneurysm. DSA and CTA showed that the aneurysm originated from the basilar apex (Figure 4C, D). The patient underwent aneurysm clipping surgery, and massive cerebral infarction in the right frontal, temporal lobe, and basal ganglia region three days after surgery.

Figure 4. Preoperative neuroimaging and angiography of patient 2. (A) Magnetic resonance imaging of patient 2 demonstrating a mass occupying the third ventricle and cisterna interpeduncularis; (B) Hydrocephalus and third ventricle mass in computed tomography (CT) scanning; (C) CT angiography demonstrating a giant intracranial aneurysm connected with basilar artery; (D) Selective cerebral digital subtraction angiography revealing the aneurysm.

Figure 5. Postoperative computed tomography scanning of patient 2: Small accumulation of blood in the ventricular system (arrow) and cerebral infarction in the right frontal, temporal lobe, and basal ganglia region.
(Figure 5). After a few days of expectant treatment, the patient discharged with a Glasgow Coma Scale (GCS) score of 5.

3.1.3. Case 3
A 53-year-old male patient experienced headaches and blurred vision. MRI showed a prefrontal mass with few enhancements and was estimated as an intracranial cavernous angioma in the report (Figure 7A-B). Neither of CTA, MRA and DSA clearly demonstrated the aneurysm because of thrombosis and calcification (Figure 6A-D). CT scanning revealed a 22 × 28 mm giant anterior communicating artery aneurysm with thrombosis and discontinuous calcification surrounding the rim of the aneurysm (Figure 7D). The patient underwent VW-MRI for risk assessment of aneurysm rupture [29]. The results showed a giant thrombotic aneurysm with unstable plaque and enhancements of the aneurysm wall, which is a sign of a high risk of rupture (Figure 7C). Aneurysm clipping, aneurysmectomy, and wrapping were performed during craniotomy. Two weeks after surgery, an intracranial hematoma occurred (Figure 8A-D). Removal of the hematoma, decompressive craniectomy and bilateral ventricular drainage were performed. The patient was discharged with GCS = E1VTM1.

3.1.4. Case 4
MRI, CT, and CTA revealed a 9 × 8 mm basilar artery apex aneurysm with calcification for a 60 years old female (Figure 9A, B). DSA confirmed an 11 × 8 × 4.1 mm aneurysm originating from the basilar artery apex (Figure 9C). Arterial stenting and aneurysm coil occlusion were performed (Figure 9D), and produced good results.

3.1.5. Case 5
A 67-year-old male patient suffered from headaches received CT and CTA, revealed a 16 × 15 × 15 mm anterior communicating artery aneurysm and mass intraventricular hemorrhage (Figure 10A, B). DSA confirmed that the aneurysm originated from the anterior communicating artery (Figure 10C, D). Laminal terminalis fenestration and aneurysm clipping were performed. The clipped aneurysm was stable on CTA during 6-month follow-up (Figure 11A–D).

3.2. Search results
The literature review delivered 47 articles. After duplicate removal, 40 articles were available for review. Four articles were additionally found by reviewing references. The rate of agreement between authors (LY and LH) for inclusion in the study was 85%. Nineteen studies met the inclusion criteria, including 22 cases.

3.3. Clinical characteristics
We included 27 nonduplicated patients in this analysis. The average age of the patients was 62 years (range, 14–82 years). The female-to-male ratio was 14:13. A total of 66.7% of aneurysms were giant aneurysms (larger than 2.5 cm), and the rest of the aneurysms were also considered as large aneurysms. The basilar artery was the most commonly affected artery, with giant aneurysms presenting as third ventricular masses (21 of 27 cases), while others developed in the anterior communicating artery, posterior communicating artery, anterior cerebral artery, and middle
cerebral artery. A total of 44.4% of aneurysms were not treated, 29.6% were treated with coil occlusion, and 25.9% were treated with craniotomy surgical procedures. Thrombosis is common in those cases, and it constitutes an important reason for misdiagnosis as tumors in radiologic reports; 63% of aneurysms exhibited significant thrombosis, 3 aneurysms were considered as complete thrombosis, and all aneurysms misdiagnosed as tumors in radiologic reports involved partial or total thrombosis. A total of 92.6% of cases represented hydrocephalus, and all of them received cerebrospinal fluid (CSF) diversion; 40% of them received septostomy, and 60% received CSF shunts, including ventriculoperitoneal (VP) shunts and ventriculo-atrial (VA) shunts and (EVDs) (Table 3).

3.4. Clinical outcomes

We collected clinical outcomes, including hemorrhagic events, artery occlusion, aneurysm progression, mortality and hydrocephalus progression, from the postoperation and follow-up periods. Forty-two percent of patients died after craniotomy surgical procedures, with only 25% of cases receiving coil occlusion and 16.7% of cases without aneurysm treatments. Aneurysms with thrombosis achieved a mortality of 35.3%, while aneurysms without thrombosis only had a mortality of 20%. Detailed clinical outcomes of hemorrhagic events, artery occlusion, aneurysm and hydrocephalus progression are shown in Tables 4 and 5.

3.5. Statistical analysis

Fisher’s precision probability test was adopted to test if there were significant correlations between different clinical characteristics and outcomes. OR and the coefficient of contingency were calculated. The statistical analysis results demonstrate that most clinical characteristics and outcomes are insignificant, and we think that these results may be attributed to the small sample size. The P values of all tests are listed in Table 6. Two significant correlations were found:

1. Aneurysm thrombosis and aneurysm misdiagnosed as tumors in radiologic reports (Fisher’s exact test 2-sided P value = 0.022 OR = 1.778 95% CI: 1.154–2.739).
2. Aneurysm treatments and aneurysm misdiagnosed as tumors in radiologic reports (Fisher’s exact test 2-sided P value = 0.006).

Then, we tested the correlation between aneurysms misdiagnosed as tumors in radiologic reports and craniotomy adoption (Fisher’s exact test 2-sided P value = 0.05 OR = 22.5 95% CI: 2.503–202.287). Statistical analysis results indicate that in the third ventricle region, aneurysms with thrombosis are easier to misdiagnose as tumors, and following the diagnosis, inappropriate craniotomy is more likely to be practiced, causing dangerous and unanticipated clinical situations.

Figure 7. Preoperative angiography of patient 3; none of them clearly demonstrated the aneurysm: (A) Computed tomography angiography; (B) Magnetic resonance angiography; (C–D) Selective cerebral digital subtraction angiography.
4. Discussion

4.1. Case series and literature review

Our cases showed features of this disease in one treatment group to minimize between-group differences at baseline. We adopted an unconventional diagnosis and treatment strategy to achieve better outcomes in these rare cases. Our cases are unique in that giant aneurysms were detected by CTA instead of DSA for the first time, which is considered to be the gold standard for aneurysm diagnosis. CTA is a standard preoperative examination in our intracranial tumor surgical procedure for detecting aneurysms before craniotomy. Several studies have determined that CTA can replace DSA for aneurysm diagnosis [30, 31, 32], especially for giant aneurysms [33, 34]. In previous cases, all patients were middle-aged and elderly, with one of our cases (case 1) being the first adolescent reported. Case 1 suggests that giant intracranial aneurysms can cause hydrocephalus in adolescents and children, so aneurysms should be included in the differential diagnosis of hydrocephalus and intracranial hypertension in adolescents. Case 3 in our series was a complete thrombosed aneurysm that required more than angiographic studies, and other examinations, such as MRI and blood coagulation function, should be included before treatment. In case 3, CTA reconstruction imaging showed greater precision than DSA. Our case is unique in that it used CTA to diagnose and depict the aneurysm when all other cases from the literature review did not apply this modality to diagnose the existence of the aneurysm. VW-MRI was also applied to assess the risk of complications in case 3.

Aneurysms presenting as third ventricular masses have been studied in several limited cases between 1979 and 2020 because of the infrequency of this disease. This study aimed to systematically review previous studies and our new series of five cases to determine the outline of aneurysms presenting as third ventricular masses on neuroimaging, treatment, and follow-up outcomes.

4.2. Preoperative neuroimaging examination

It is very important in clinical practice to select simple and effective examination methods among various neuroimaging techniques to improve the diagnostic accuracy of brain space-occupying lesions. In cases we gathered, all patients were hospitalized with clinical presentation and received a CT scan or MR scan as the preferred inspection. All the third ventricular masses were found in the first neuroimaging examination, and characteristics such as the size of the lesion and hydrocephalus were identified. Although MRI provides the precise location of the mass and the relationship of the lesion to surrounding structures and CT scans can detect mural calcification, sometimes it is difficult to differentiate giant intracranial aneurysms with thrombosis from intraventricular tumors. In addition, this type of patient is usually received by the neuro-oncology department instead of the cerebrovascular surgery department, which has less experience in treating aneurysms, meaning that craniotomy could take place for the resection of the "tumor", which is very hazardous for the patient. Intraoperative hemorrhage has been reported in previous literature [10]. Furthermore, in one case, the aneurysm, determined under neuroendoscopy, was mistakenly diagnosed as a hematoma [23]. To avoid such adverse events, angiography is required to determine the substance of the lesions. DSA remains the gold standard for evaluating intracranial aneurysms with excellent spatial and temporal resolution. In previous cases, DSA was used as the gold standard for diagnosis. Magnetic resonance angiography (MRA) was used in some cases alongside DSA with no reports of misdiagnosis in cases we
collected, and one case reported a positive result on MRA and negative result on DSA [24]. The DSA for case 3 in our series also obtained unclear results because of thrombosis and calcification. The diagnosis was made comprehensively according to VW-MRI, CT, and DSA, suggesting that DSA is not the only choice for the diagnosis of giant aneurysms. DSA evaluates the circulation of aneurysms, which is not enough for complex cases such as aneurysms presenting as a third ventricular mass. Luminal size/patency evaluation, the relationship between aneurysms and surrounding structures, and the calcification of the aneurysmal sac, which are significant for evaluating aneurysmal rupture risk, choosing treatment methods, and making prognosis, cannot be obtained through DSA [35, 36]. In cases of giant aneurysms and aneurysms with mass effects, angiographies such as CTA and MRA present a more comprehensive evaluation than DSA.

4.3. Use of CT angiography

CT angiography is increasingly becoming a diagnostic tool for vessel pathology [33]. Aneurysms larger than 3 or 4 mm can be recognized with CTA. Teksam et al. [32] reported that CTA missed only seven out of 106 cases, and of these, only two were larger than 4 mm. In cases with aneurysm rupture and cerebral hemorrhage, which may require emergency surgical evacuation, CTA is a quick and obviously better vascular evaluation tool than DSA. Because calcification often appears in vessel pathology and noncooperative patients make MR or MRA impossible, CTA also has advantages over MRA in certain aspects. According to a recent study on imaging morphology [34], because of the multpass or recirculation phenomenon of the contrast medium within the aneurysm, CTA is superior to 3D time-of-flight MRA, contrast-enhanced MRA, and even DSA in the visualization of the patent aneurysmal lumen [37]. All these characteristics of CTA made it suitable for the evaluation of giant intracranial aneurysms, but it was not applied in all cases reported in the literature of giant aneurysms adjoining the third ventricle. Our study’s reporting of CTA as a diagnostic and follow-up examination and the resultant precise evaluations filled the void of neuroimaging examination of this rare and complex disease. All five patients underwent CTA, which revealed aneurysms before surgery and at postoperative follow-up. CTA reconstruction imaging of the intracranial arterial system is reliable and economical for revealing intracranial aneurysms. Applying CTA to detect intracranial aneurysms has become an imperative preoperative neuroimaging examination for patients with skull base tumors in our ward due to the efficiency, convenience, and reasonable cost of CTA. With preoperative CTA, misdiagnosis of a third ventricular aneurysm and other vascular malformations can be discovered at an acceptable cost. However, CTA has limitations, such as beam-hardening artifacts related to coil embolization in postoperative patients, which can be found in all of our follow-up CT/CTA examinations. However, due to its viability, fast imaging, and high spatial resolution, it remains the first choice to follow-up postoperative patients with aneurysms.

4.4. Vessel wall magnetic resonance imaging

Another neuroimaging examination we applied was VW-MRI, a neuroimaging technology for indicating inflammatory processes in vessel walls. Enhancement of the aneurysm wall on VW-MRI is assumed to be an imaging marker of aneurysm instability and a higher risk of rupture [38,
Case 3 in our series underwent VW-MRI before surgery to evaluate the risk of aneurysm rupture because of discontinuous calcification surrounding the rim of the aneurysm found on CTA. The patient’s diabetes may contribute to the risk of aneurysm rupture and hemorrhage. Patients with diabetes had a significantly higher prevalence of calcification and high-risk plaques on vessel walls, which are risk factors for aneurysm rupture and hemorrhage [40]. Interestingly, some recent research suggests that diabetes could be a protective factor against the rupture of intracranial aneurysms [41, 42]. Enhancement of the aneurysm wall and anterior cerebral artery was significant on VW-MRI, while the aneurysm was unclear on DSA. The aneurysm appeared clear with thrombosis in MRI imaging. Considering the thrombus inside the aneurysm alongside the mass effect it caused, aneurysm clipping and aneurysmectomy were applied as a confined operation. Aneurysm wrapping was performed to prevent hemorrhage. However, hemorrhage still occurred after two weeks. The results demonstrate the value of VW-MRI in evaluating the risk of aneurysm rupture in a certain way.

In conclusion, intracranial aneurysms at critical positions, such as the third ventricle, or aneurysms causing clinical syndromes require multiple neuroimaging examinations for differential diagnosis and treatment planning. We recommend CTA for detecting aneurysms in preoperative examinations and aneurysm follow-up and VW-MRI for evaluating the risk of aneurysm rupture for giant aneurysms with thrombosis.

4.5. Cerebrospinal fluid diversions

Twenty-five (92.6%) patients reported having different degrees of hydrocephalus. Certainly, there is no optimal management option for this delicate and complex situation. CSF diversions have been performed in most patients as a symptomatic treatment to relieve the brain from CSF pressure. Multiple methods are available, including VP shunting, ventriculoatrial (VA) shunting, eternal ventricular drainage (EVD), septostomy with craniotomy, and endoscopic third ventriculostomy (ETV). VP shunting was the most commonly used procedure in the past, with 12 of the 25 patients undergoing this procedure, although all 12 cases were from 10 years ago. Six patients received ETV. Four patients received EVD, including one case from our series who received EVD for postoperative intracranial hemorrhage. Four of the 27 patients underwent ventriculostomy with craniotomy, including two cases in our series. Two patients underwent VA shunting. A previous study showed that VP shunting [43] is the most common type of shunting procedure because it is convenient and effective, and studies have shown no significant differences in terms of the outcome between the different kinds of shunting methods (VP, VA, and lumboperitoneal shunting). ETV has become widely used because of improvements in neuroimaging, operation instruments, and stereotaxic neuronavigation systems in recent years. A meta-analysis based on randomized controlled trials revealed that in obstructive hydrocephalus, ETV had significantly lower blockage rates and could reduce the risk of postoperative hematoma compared with VP shunting [44]. In our study, the difference between the death rate in the septostomy group and in the shunting group was not significant. These deaths were caused by aneurysm rupture and hemorrhage. According to a literature report, a reduction in intracranial pressure after CSF diversions can increase the aneurysmal transmural pressure, shift the formed clot inside the aneurysms, and cause a higher risk of rupture [45, 46, 47]. Therefore, according to the theory, ETV should be performed with other treatments to stabilize or remove aneurysms. The case results fit this theory: only one out of three deaths among patients who received ETV was caused by aneurysm rupture (the other two were caused by thrombosis), and that case is the only one without treatment for...
Figure 11. Postoperative computed tomography (CT) scanning and angiography of patient 5: (A) CT scanning after the operation; (B) CT angiography after the operation; (C) CT scanning after six months; (D) 6-month follow-up results of patient 5 demonstrated by CT angiography: the clipped aneurysm remained stable.

| Author           | Thrombosis | A Treatment | H Treatment | Hemorrhage | Misdiagnosis | Occlusion | Progression | Death |
|------------------|------------|-------------|-------------|------------|--------------|-----------|-------------|-------|
| Babu et al.      | T          | Craniotomy  | Shunt       | F          | T            | F         | F           | T     |
| Koga et al.      | T          | None        | Shunt       | F          | F            | F         | F           | F     |
| Piek et al.      | T          | None        | Shunt       | T          | T            | F         | F           | F     |
| Bose et al.      | T          | Craniotomy  | Shunt       | T          | T            | F         | F           | T     |
| Borrie et al.    | F          | None        | Shunt       | F          | F            | F         | F           | F     |
| T                 | None       | Shunt       | F           | F          | F            | F         | F           | F     |
| Ishibashi et al. | F          | None        | Shunt       | F          | F            | T         | F           | F     |
| Smith et al.     | T          | Craniotomy  | Shunt       | F          | T            | F         | F           | F     |
| Koyama et al.    | T          | None        | Shunt       | T          | F            | F         | F           | T     |
| Hongo et al.     | F          | None        | Septostomy  | T          | F            | F         | F           | T     |
| Ishihara et al.  | F          | Coil occlusion | Shunt     | T          | F            | F         | F           | F     |
| Gelal et al.     | T          | None        | Shunt       | F          | F            | F         | F           | F     |
| Nabika et al.    | F          | None        | Shunt       | T          | F            | F         | Aneurysm    | T     |
| Liu JK et al.    | T          | Craniotomy  | Septostomy  | F          | T            | F         | F           | F     |
| Tsuchumi et al.  | F          | Coil occlusion | Shunt     | T          | F            | F         | Hydrocephalus | F     |
| Stachura et al.  | F          | None        | Septostomy  | F          | F            | F         | F           | F     |
| Oertel et al.    | T          | None        | Septostomy  | F          | F            | F         | F           | F     |
| T                 | Coil occlusion | Septostomy  | F          | F           | T            | F         | T           | F     |
| T                 | Coil occlusion | Septostomy  | F          | F           | T            | F         | T           | F     |
| Castro et al.    | T          | None        | Shunt       | F          | F            | F         | F           | F     |
| Sato et al.      | F          | Coil occlusion | Septostomy | F          | F            | F         | Aneurysm/Hydrocephalus | F     |
| Kalousek et al.  | T          | Coil occlusion | Shunt     | F          | F            | F         | F           | F     |
| Case 1           | T          | Coil occlusion | Septostomy | F          | T            | F         | F           | F     |

(continued on next page)
**Table 3 (continued)**

| Author | Thrombosis | A Treatment | H Treatment | Hemorrhage | Misdiagnosis | Occlusion | Progression | Death |
|--------|------------|-------------|-------------|------------|--------------|-----------|-------------|-------|
| Case 2 | F          | craniotomy  | None        | F          | F            | T         | F           | F     |
| Case 3 | T          | craniotomy  | None        | T          | T            | F         | F           | T     |
| Case 4 | F          | coil occlusion | None    | T          | F            | F         | F           | F     |
| Case 5 | F          | craniotomy  | septostomy  | F          | F            | F         | F           | F     |

T/F, true/false; A treatment, aneurysm treatment; H treatment, hydrocephalus treatment.

**Table 4. Different treatment for aneurysm and clinical outcomes.**

| Total | Complete Thrombosis | Partial Thrombosis | None |
|-------|----------------------|--------------------|------|
|        |                      |                    |      |
| Hemorrhagic events | 9 (33.3%) | 1 (33.3%) | 4 (28.6%) | 4 (40%) |
| Occlusion | 4 (14.8%) | 0 | 2 (14.3%) | 2 (20%) |
| Aneurysm progression | 2 (7.4%) | 0 | 0 | 2 (20%) |
| Mortality | 8 (29.6%) | 1 (33.3%) | 5 (35.7%) | 2 (20%) |
| Misdiagnosis | 6 (22.2%) | 2 (66.7%) | 4 (28.6%) | 0 |

The percentages stand for every complication rate in a treatment group.

**Table 5. Aneurysm thrombosis and clinical outcomes.**

| Total | Complete Thrombosis | Partial Thrombosis | None |
|-------|----------------------|--------------------|------|
|        |                      |                    |      |
| Hemorrhagic events | 9 (33.3%) | 1 (33.3%) | 4 (28.6%) | 4 (40%) |
| Occlusion | 4 (14.8%) | 0 | 2 (14.3%) | 2 (20%) |
| Aneurysm progression | 2 (7.4%) | 0 | 0 | 2 (20%) |
| Mortality | 8 (29.6%) | 1 (33.3%) | 5 (35.7%) | 2 (20%) |
| Misdiagnosis | 6 (22.2%) | 2 (66.7%) | 4 (28.6%) | 0 |

The percentages stand for every complication rate in a treatment group.

4.6. Treatments for aneurysms

General treatment of aneurysms includes procedures such as craniotomy (mainly clipping) and endovascular treatment (mainly aneurysm coiling) [48]. Generally, outcomes in patients treated with clipping are better than those treated with surgical clipping in terms of long-term dependency and mortality rate [49]. With various methods to treat hydrocephalus, the options for aneurysms are limited, and the aneurysm neck is usually not clear (e.g., Case 1) or too broad to clip. Our statistical results show no significance among different treatments for aneurysms, which may be caused by insufficient sample size. In our literature review, only two patients received aneurysm clipping, and eight patients received aneurysm coil occlusion. Interestingly, two patients who underwent aneurysm clipping had an excellent prognosis when the results of aneurysm coil occlusion were not satisfactory. After these patients underwent aneurysm coil occlusion, one died from cerebral infarction; one died from thrombogenesis of the basilar artery [25]; one developed hydrocephalus [21] and underwent a second operation; one patient’s aneurysm developed and progressively compressed the right thalamus and midbrain and they underwent a second operation [20]; and one died from aneurysm rupture [21]. Only two patients (including the present case) received satisfactory results [19]. In our cases, two patients (case 1 and case 4) who received aneurysm coil occlusion achieved a good prognosis, particularly case 1, who underwent follow-up after aneurysm coil occlusion for two years and obtained a favorable prognosis, and two of the three patients (case 2 and case 3) who underwent aneurysm clipping had an unfavorable prognosis due to postoperative hemorrhage. A previous study of middle aneurysms showed that cerebral infarction was the main cause of death after two kinds of treatment [50], and clipping had a lower death rate (0.3%–1.1%). Nevertheless, aneurysms presenting as third ventricular masses are mostly giant aneurysms with hydrocephalus; the prognosis of this disease is much worse, and the operation is much harder than for general middle aneurysms. The different prognostic trends between the literature reports and our cases may be attributed to the technical development of aneurysmal coiling over time. Developing a standardized treatment protocol with limited case reports and huge heterogeneity between cases is impractical. Aneurysm coil occlusion with CSF diversion, if necessary, seems to be a favorable option for treating giant aneurysms presenting as third ventricular masses with hydrocephalus because these aneurysms are usually giant aneurysms with broad necks. The goal of the treatment should be to stabilize the aneurysms and release hydrocephalus.

**Table 6. Fisher’s Exact Test P values for Correlation between Clinical Characteristics and Outcomes.**

|            | Hemorrhage | Misdiagnosis | Occlusion | H progression | A progression | Death |
|------------|------------|--------------|-----------|---------------|---------------|-------|
| Before/After 2005 | 0.42 | 0.385 | 0.526 | 0.222 | 1 | 0.678 |
| Aneurysm site | 0.628 | 0.29 | 0.545 | 1 | 1 | 1 |
| Giant Aneurysm | 0.667 | 1 | 1 | 1 | 0.538 | 0.201 |
| Thrombosis | 0.411 | 0.022 | 1 | 0.157 | 0.157 | 0.405 |
| A treatment | 1 | 0.006 | 0.789 | 0.14 | 1 | 0.752 |
| H treatment | 0.103 | 1 | 0.39 | 1 | 1 | 1 |

A, aneurysm; H, hydrocephalus.
Based on the results presented above, the treatment for giant intracranial aneurysms mimicking an intraventricular tumor is still nonideal. It remains a complex and dangerous clinical challenge for both diagnosis and treatment. Further investigations and case reports should be conducted in the future.

5. Conclusions

Thrombosed aneurysms sometimes can mimic third ventricular tumors without enough examinations and clinical experience, and misdiagnosis can be made and bring extra risk to the patients. The use of CTA is beneficial for preoperative aneurysm identification in patients planning to have a craniotomy. Thrombosed aneurysms should be considered as a differential diagnosis in patients with third ventricular masses. Aneurysm coil occlusion might be a favorable treatment, and theoretically, CSF division should be performed with treatment for aneurysms because monotherapy may increase the risk of aneurysm rupture. However, further studies should be conducted to confirm our observations.

Declarations

Author contribution statement

Li Yuzhe: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Wrote the paper.

Li Haoyu: Performed the experiments; Wrote the paper.

Chen Bo: Performed the experiments.

Long Wenyong: Analyzed and interpreted the data; Wrote the paper.

Liu Qing: Conceived and designed the experiments; Contributed reagents, materials, analysis tools or data.

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Data availability statement

Data will be made available on request.

Declaration of interest’s statement

The authors declare no conflict of interest.

Additional information

No additional information is available for this paper.

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