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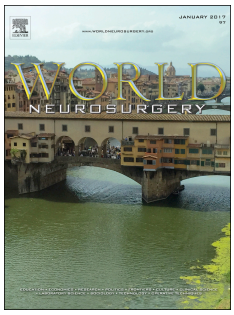

Misdiagnosis and delay of diagnosis in hemorrhagic meningioma: a case series and review of the literature

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Title: Misdiagnosis and delay of diagnosis in hemorrhagic meningioma: a case series and review of the literature

Running head: Misdiagnosed hemorrhagic meningioma

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ABSTRACT

OBJECTIVE: To evaluate the clinico-radiological characteristics of hemorrhagic meningiomas (HMs) that are missed or misdiagnosed on radiological imaging studies.

METHODS: Clinical and radiological data from six patients with HM who were initially misdiagnosed were collected and recorded respectively. In addition, we performed a literature review for misdiagnosed HM and summarized the results.

RESULTS: Five of the six patients with misdiagnosed HM were female and one was male. Both computed tomography (CT) and magnetic resonance imaging (MRI) were performed in four patients and CT alone was performed in two. On CT, the HM was heterogeneously hyperdense in five patients and iso-dense in one. In all four patients who underwent MRI, the HM was mixed iso- and hypointense on T1-weighted imaging and heterogeneously hyperintense on T2-weighted imaging. Marked heterogeneous contrast enhancement was observed in two patients, strong rim enhancement in one, and peripheral enhancement in one. The dural tail sign was seen in only one patient. The initial radiological misdiagnoses were subdural hematoma (n

= 1), malignant glioma (n = 1), ruptured arterial aneurysm (n = 1), metastasis (n = 2) and uncertain (n = 1). In the literature review, 22 cases of HM diagnostic error were collected. The main misdiagnoses were subdural hematoma (27.3%), traumatic hematoma (13.6%), vascular anomaly (13.6%), malignant glioma (4.5%) and metastasis (4.5%).

CONCLUSIONS: Our study showed that HM patients with inadequate imaging evaluation, a small tumor associated with massive hematoma and atypical imaging features was more likely to be misdiagnosed.

Key words: Meningioma; Hemorrhage; Computed tomography; Magnetic resonance imaging; Misdiagnosis

INTRODUCTION

Intracranial hemorrhage associated with meningioma is rare and occurs in only approximately 1.3% to 2.4% of meningiomas.[1-3] The mechanisms underlying meningioma hemorrhage remain unclear.[2, 4, 5] Mortality appears to be higher in patients with meningioma presenting with symptomatic hemorrhage than in patients with tumors that have not bled and is estimated to range between 28% and 55%.[2, 6] Early diagnosis and appropriate treatment is key in these patients, which can lower the mortality to 13.1%.[3] Typical meningiomas are easy to distinguish from other intra-axial tumors and vascular anomalies on radiologic examinations.[7] However, the imaging features of hemorrhagic meningioma (HM) have not been fully described because of their rarity and misdiagnosis may result.[8] Numerous cases of missed HMs and those misdiagnosed as other intra- and extra-axial entities such as malignant tumor or giant arterial aneurysm have been reported.[1, 4, 6, 9-25] Misdiagnosis or delayed diagnosis can lead to inadequate investigations and preparation before tumor surgery, with potentially fatal consequences for the patient.[1, 2, 10, 11, 14, 15, 26, 27] Furthermore, the clinical management and prognosis of HM and its mimics can differ significantly. Therefore, distinguishing them is essential.

Nineteen patients with HM were treated at our institution from 2010 to 2020 and six were radiologically misdiagnosed. This study summarizes the radiographic and clinical characteristics of these six patients and tumors and reviews the relevant literature.

MATERIALS AND METHODS

Patients and data collection

We searched the pathology database of the First Affiliated Hospital, Shantou University Medical College, Shantou, Guangdong, China and identified 651 patients who were admitted with intracranial meningioma and underwent surgery between January 2010 and October 2020. Patients with an HM and the following characteristics were included in the study: (1) missed diagnosis on computed tomography (CT) and/or magnetic resonance imaging (MRI), i.e. the meningioma was not identified on initial radiological images but found during surgery and proven pathologically; (2) misdiagnosed as another entity such as cerebral aneurysm, glioma, metastatic tumor, or other; and (3) uncertain diagnosis. We excluded 630 patients with non-hemorrhagic meningioma. Two HM patients were excluded because CT and MRI findings were unavailable. Thirteen HM patients were excluded because they were diagnosed correctly on initial CT and/or MRI. Finally, six HM patients were included for analysis. This study received institutional review board approval. The requirement for written informed consent was waived.

Demographic, clinical, radiological, surgical, and outcome data were collected and recorded. Pre-operative imaging characteristics of the misdiagnosed HMs, including tumor location, size (greatest diameter), shape (regular or irregular), hemorrhagic type (intra- and/or extra-tumoral, i.e. subarachnoid hemorrhage, (SAH), subdural hematoma (SDH), peritumoral hemorrhage), signal density and/or intensity

characteristics, presence of intralesional necrosis or calcification, dural tail sign, peritumoral brain oedema, and contrast enhancement pattern (uniform, heterogeneous, peripheral, rim, or none), were retrospectively reviewed and recorded by two radiologists (R.H and R.Z.) with 8 and 15 years of experience, respectively.

Literature review

Two authors (R.H. and L.C.) conducted a literature search for articles published before March 2021 using the search words 'hemorrhage' and 'meningioma' in the PubMed database. After duplicate outcomes were removed, potentially relevant articles were included after a full-text review. Additional articles were obtained from references listed in the selected articles. Controversial results were resolved by consensus among the senior authors (R.Z. and Y.L.). Only articles fulfilling the following criteria were included in the systematic review: (1) full-text English-language case series and reports; and (2) the meningioma was missed on initial radiological imaging or incorrectly diagnosed as another entity, or the nature of the lesion was uncertain. We excluded articles that did not report sufficient radiological or pathological data and those that described post-mortem imaging studies or extracranial HM. This review conforms to the "Preferred Reporting Items for Systematic Reviews and Meta-Analyses" (PRISMA) statement.[28]

RESULTS

Our case series

Radiologically misdiagnosed HMs

The clinico-pathological features of all six patients with an initially misdiagnosed HM are summarized in **Table 1**. One patient was male and five were female. Median age at diagnosis was 40 years (range, 19–59). Cases 2 and 3 had a history of hypertension. No patient had a history of trauma, malignant tumor, bleeding tendency or other predisposing factors for hemorrhage such as antiplatelet or anticoagulant medication. All six patients experienced a stroke-like episode characterized by the sudden onset of acute headache, nausea and vomiting, blurred vision, hemiparesis and/or altered consciousness of 2 hours to 1 month in duration.

All patients were treated with surgical tumor excision and hematoma removal in one stage (Simpson grade I excision in five patients, Simpson grade II excision in one). Two patients underwent emergency surgery because of progressive neurologic deficit and altered consciousness (cases 5 and 6). Histopathologically, three tumors were fibrous; the remaining three were anaplastic, meningothelial and transitional, respectively (**Table 1**). Median follow-up was 62 months (range, 42–114). No patient experienced tumor recurrence.

The HM radiological characteristics are presented in **Table 2**. Both CT and MRI were performed in four patients. CT alone was performed in the other two (cases 5 and 6) because of their progressive neurologic deficit and altered consciousness (**Table 2**). Pre-operative CT angiography (CTA) was performed in five patients and digital subtraction angiography (DSA) in one. Case 6 was suspected to have a vascular malformation. Angiographic imaging in the other five patients was negative.

Three HMs were located at the convexity; the remaining three were located in the tuberculum sellae, along the interhemispheric fissure and within the posterior cranial fossa, respectively. Mean largest tumor diameter was 3.9 cm (range, 2.5–7.4). Four patients (66.7%) had irregular tumor margins. A massive amount of hemorrhage was observed in five patients; the remaining patient (case 2) had a small amount of SAH. Four patients had both intra- and extra-tumoral hemorrhage (**Figure 1**) and two (cases 2 and 3) only had SAH and intratumoral hemorrhage (**Figure 2**), respectively. On CT, the HM was heterogeneously hyperdense in five patients (83.3%) and iso-dense in one (16.7%). In the four patients who underwent MRI, all HMs exhibited heterogeneous signal intensity on both T1- and T2-weighted imaging (**Figures 1, 2**). On post-contrast imaging, heterogeneously strong tumor enhancement was seen in two patients, strong rim enhancement in one (**Figure 2e**), and strong peripheral enhancement in the other (**Figure 1d**). Peritumoral brain oedema was seen in all six patients, intratumoral necrosis in four, and the dural tail sign in only one (**Figure 1d**). Intralesional calcification and adjacent bone hyperostosis were not observed.

The initial radiological diagnosis based on CT in the six study patients was uncertain in three (cases 1, 2 and 5), SDH in one, metastatic tumor in one, and vascular anomaly in one (**Figure 3**). Based on MRI (four patients), the diagnosis was metastatic tumor in two, giant cerebral aneurysm in one, and high grade glioma in one.

Representative case of a correctly diagnosed HM

A 33-year-old female was admitted with sudden onset of a severe headache,

vomiting, and deterioration in level of consciousness. The patient had no history of trauma or neoplasm. Her Glasgow Coma Scale score was 13 on admission. Blood coagulation and tumor marker testing were within normal range. MRI of the brain demonstrated a 3.7- × 4.7- × 5.2-cm left frontal parafalcine tumor with intratumoral hemorrhage (**Figure 4**). The tumor was iso- and hyperintense on T1-weighted imaging (**Figure 4a**) and mixed hypo- and hyperintense on T2-weighted imaging (**Figure 4b, 4c**). Peritumoral cerebral oedema was present. After contrast administration, tumor enhancement was strong and heterogeneous; a typical dural tail sign was observed (**Figure 4d–f**). CTA of the head was unremarkable. Based on MRI, the initial diagnosis was HM.

A left frontal craniotomy was performed and total excision of the tumor and attached dura was achieved (Simpson grade I). Her post-operative neurological examination was normal. Histological examination of the tumor revealed elongated cells with small regular oval nuclei and a wavy arrangement. MIB-1 labelling index was well below 5%. Numerous large blood vessels and hemosiderin deposits were visualized. The histological diagnosis was angioblastic meningioma, World Health Organization grade I.

Literature review

Our systematic review identified 22 English language articles that fulfilled our inclusion criteria (**Figure 5** and **Table 3**). Eight patients were male and 14 were female, corresponding to the predominance of females affected by meningioma. The

age of presentation varied significantly: mean age was 55.7 years but ranged from 7 to 91 years. All 22 patients experienced a stroke-like episode and/or altered consciousness. Three had a history of trauma and two had a history of malignant tumor. Thirteen patients underwent MRI and nine underwent CT alone. Seven HMs were missed on the initial CT scan. Among these, six were diagnosed as SDH and one as intracerebral hemorrhage. Three patients were misdiagnosed as traumatic hematoma on CT (one hemorrhagic contusion and two traumatic SDH). Only three patients were suspected to have HM based on MRI. Other initial diagnoses included metastatic tumor (4.5%, 1/22), vascular anomaly (13.6%, 3/22) and glioma (4.5%, 1/22). Surgery was performed in all 22 patients; however, four tumors were incidentally discovered during surgery and 2 patients were operated upon twice for SDH before the unexpected meningioma was diagnosed by MRI. Histopathologically, five meningiomas were meningothelial (22.7%), four were fibrous (18.2%), three were transitional (13.6%), three were atypical (13.6%), two were microcystic (9.1%), one was malignant (4.5%) and one was chordoid (4.5%).

DISCUSSION

Clinical Features

The differential diagnoses of any intracranial hemorrhage includes traumatic head injury, systemic hypertension, ruptured aneurysm/cavernoma/arteriovenous malformation/arteriovenous fistula, hemorrhagic arterial infarction, venous infarction,

venous sinus thrombosis, hematological disorders, coagulopathies, disseminated vascular coagulopathy, cerebral amyloid, vasculitis, drug abuse, fungal infection and hemorrhage into a tumor, which constitutes 3%-4% of all intracranial hemorrhages and is poorly reported in literature. Famous tumors to have hemorrhage or infarction are pituitary adenomas. The highest incidence is seen in glioblastoma multiforme. However, the list is long and includes: metastasis, ependymoma, central neurocytoma, choroid plexus, carcinoma, ganglioglioma, astrocytoma, hemangiopericytoma, oligodendroglioma, pineocytoma, germinoma, schwannomas, chordomas, teratoid-rhabdoid tumor, lymphoma and others.[29-31] Meningiomas manifesting itself as intracranial bleeding are also but rarely reported, with a reported incidence of 1.3%-2.4%.[32, 33]

In our series, the meningioma hemorrhage incidence over a 10-year period was approximately 2.9%, which is slightly high. Among these patients, six were radiologically misdiagnosed. An extensive systemic review of the reported data revealed 22 missed cases of HMs. Among the cohort of 28 patients (22 cases in the literature and 6 in our series), 15 were females and 13 males. 27 out of 28 of whom experienced a stroke-like condition, while history of trauma was found in 3, history of hypertension in 2 and history of malignant tumor in 2. All the 28 patients underwent surgery. Histological findings were those of fibrous type in 7, meningeothelial in 6, transitional in 4, microcystic in 2, anaplastic in 4 and malignant in 1 out of 28 patients, respectively. To our knowledge, this is the first study to analyze the causes of HM misdiagnosis in detail.

Proposed Pathophysiological Mechanism

Hemorrhage into meningioma can occur spontaneously, postoperatively, postradiosurgery and post embolization. The exact mechanisms responsible for meningioma hemorrhage are not yet well understood. Several have been proposed, such as hypervascularity of meningiomas, thin walled neovasculature, rupture of bridging veins, tortuous feeding arteries and intratumoral necrosis or infarction.[3, 4, 6, 23-25, 32] Other factors that may increase bleeding propensity in meningiomas include convexity group, angiomatous histological type and malignant meningiomas, seizures, trauma, hypertension and pregnancy.[2, 3, 13, 33] Nevertheless, none of these mechanisms alone can explain the phenomenon; therefore, various combinations of these factors are likely related to HM pathogenesis.

Along with histological type and tumor location, the mechanism of hemorrhage in meningiomas also may vary according to the type of hemorrhage.[34] These tumors exhibit various bleeding patterns: some bleed only intratumorally, some only extratumorally, and some manifested both. According to the majority of the authors, the most common locations of SDH were the convexity (66%), while SAH was usually associated with falx/parasagittal meninginioma.[18, 35] Stretching and rupture of subdural bridging veins may explain only the extratumoral hemorrhage involving SDH or/and SAH. On the other hand, some authors have proposed that rupture from weakened or unusual blood vessels is usually associated with intratumoral hemorrhage and have emphasized a high risk of hemorrhage in angiomatous and

malignant meningiomas.[5, 7, 8]

Diagnostic Errors Analysis

Generally, meningioma diagnosis is usually straightforward based on clinical presentation and typical radiological findings.[5, 7, 8] However, HM can be misdiagnosed or completely missed in clinical practice. Based on our series and the available data collected, diagnosis was missed on MRI in 14 out of 28, 11 on CT, and 3 on both. Missed diagnosis was subdural hematoma in 11, traumatic hematoma (subarachnoid and/or intraparenchymal) in 8, vascular anomaly in 4, metastasis in 3 and glioma in 2 out of 28 patients respectively. The underlying causes of diagnostic error are multifactorial. Blood clot can obscure many details. This coupled with lack of awareness of the differential diagnosis of an intracranial bleed and associated with the widely variable individual subjective analysis, can lead to morbidity and mortality of as high as 28-55%.[2, 6, 26] Therefore, recognizing and understanding the spectrum of imaging features of misdiagnosed HMs can aid in accurately diagnosing and managing these challenging tumors.

Missed diagnosis

In clinical practice, the preoperative diagnosis of intracranial extra-axial lesion was recognized or suspected based on radiological studies in all previously reported cases. Even though some meningiomas presented with small foci of intratumoral hemorrhage, this pattern tends to preserve some visualization of the underlying neoplasm and causes a less rapid neurological decline.[10, 14] A more definitive

oncologic work-up can be performed in these patients, as shown by our representative case. However, discovery of an unsuspected meningioma may occur during surgery because abnormal tissue not appreciated on preoperative imaging is clearly recognized.[1, 10, 14] Many reasons may contribute to missing the diagnosis. A massive acute blood clot (hyperdense on CT, hyperintense on T1-weighted imaging) can obscure a small underlying tumor or be so bright on non-contrasted imaging that contrast enhancement cannot be appreciated. Moreover, CTA and DSA might not show tumor staining because of hematoma-induced direct vessel compression and/or locally elevated intracranial pressure.[1, 14, 19, 21]

Based on our experience and literature review, we suggest that several findings should raise clinical concern for a possible underlying neoplasm: (1) bony alterations including hyperostosis or erosive changes; (2) focal cerebral and venous sinus distortion; (3) intra-tumoral calcification; (4) perifocal brain oedema; (5) variable signal intensity/density within the hemorrhagic area; and (6) tumor staining or marked vascularity along the hematoma periphery on CTA. Moreover, some authors have suggested that serial imaging studies (CTA, enhanced CT or/and enhanced MRI) should be performed to detect possible neoplasms and allow early treatment.[1, 4, 5, 10, 14, 24]

Misdiagnosis as other tumors

Several atypical imaging features, including peripheral or rim enhancement resulting from cystic change with hemorrhage, absent dural tail sign, extensive peritumoral oedema and uncommon tumor location, may contribute to misdiagnosis

or reduced diagnostic confidence.[7, 23, 25, 36] Jung et al.[37] theorized that intratumoral cysts develop via microcystic degeneration, ischemic necrosis and/or hemorrhage, which may lead to diagnostic confusion for patients with cystic meningiomas (as shown by our case 3). Other tumors that may show cystic change include high-grade glioma, hemangioblastoma and metastasis. The dural tail sign is usually considered characteristic of meningiomas; however, it may also be seen in other neoplastic processes involving the dura that have considerably different prognoses and treatments. In cases of dural mass with hemorrhage, dural metastasis is obviously the main differential diagnostic consideration. Dural metastases often manifest as solitary lesions and may appear as linear dural thickening or nodular dural lesions with focal or diffuse involvement. Although the presence of dural enhancement adjacent to osseous involvement may represent dural invasion, it may represent a reactive dural response to adjacent metastatic disease. Lui et al.[38] suggested that perfusion imaging may be of benefit to differentiate dural metastases from meningioma by using first-pass wash-in characteristics. They found that relative wash-in time was lower in metastases than in meningiomas.

In some cases, there may be considerable morphological overlap between HMs and other entities.[7, 30, 39, 40] Under these circumstances, distinguishing HM from other tumors might be difficult even with the use of multimodality imaging. Nonetheless, these cases highlight the various manifestations of HMs and their mimics. HMs should be considered in the differential diagnosis in patients presenting with acute intracranial hemorrhage. When the preoperative radiological diagnosis is unreliable,

pathological molecular diagnosis is required to clarify.

Misdiagnosis as traumatic hematoma

Although none of our patients has a history of trauma at presentation, minor head trauma has been proposed as a risk factor for intracranial hemorrhage arising from a meningioma. HM misdiagnosed as traumatic hematoma on head CT has been previously reported.[14, 17, 24] In these cases, the hematomas on CT obscured the meningiomas, which were all incidentally discovered during surgery. After retrospectively reviewing the CT imaging, the tumors were identified as biconvex high-density areas separate from the surrounding SDH.[14, 17, 22, 24] Signal intensity or density in these lesions was heterogeneous because of intratumoral hemorrhage. Imaging findings atypical for simple traumatic hematoma should raise concern for an underlying meningioma. Radiologists and neurosurgeons should be aware of these signs, especially in patients who require emergent surgery that precludes preoperative MRI. In patients with intracranial traumatic hemorrhage who do not require emergency work-up and treatment, enhanced MRI should be performed to further investigate.

Misdiagnosis as vascular anomaly

Meningioma, including HM, can be misdiagnosed as cerebral aneurysm or vascular anomaly.[7, 20, 21] Basil et al.[21] reported a jugular foramen meningioma that presented with hemorrhage and was initially believed to be a thrombosed aneurysm. In our series, case 1 presented with mixed intra- and extra-tumoral suprasellar hemorrhages. We considered two possible diagnoses, ruptured giant anterior

communicating artery aneurysm and hemorrhagic tuberculum sellae meningioma. Case 6 presented with intratumoral hemorrhage and SAH on CT that was suspected to have resulted from a vascular anomaly.

In complicated circumstances where a meningioma coexists with a vascular anomaly (aneurysm, cavernous malformation or arteriovenous malformation), the correct preoperative diagnosis may be difficult, which poses a significant management dilemma.[9, 15, 20, 40-42] Three cases of meningioma associated with ruptured aneurysm have been previously reported.[9, 15, 20] All three patients presented with massive hemorrhage resulting from aneurysmal rupture; HM was suspected in one based on MRI. In our series, all six patients underwent angiographic evaluation of the cerebral vasculature and no vascular abnormalities were found. At present, there is no consensus that preoperative angiography should be routinely performed in patients with intracranial tumors; therefore, the incidence of co-existing meningiomas and intracerebral aneurysms may be underestimated.[41, 43] We suggest that preoperative MRA or CTA is necessary in brain tumor patients to confirm the existence of any vascular lesions so they may be appropriately addressed during surgery.

This study has several limitations, including a small number of cases, its retrospective nature, and a lack of statistical analysis. A selection bias may have been introduced because final diagnoses were known. Despite these limitations, to our knowledge, this study is the first to address diagnostic errors in HM and demonstrate the radiological features of HM that are missed or misdiagnosed.

CONCLUSIONS

Although relatively rare, HM can be missed or misdiagnosed as vascular anomaly, SDH, traumatic cerebral hematoma, high-grade glioma or metastasis on CT/MRI. Our study showed that HM patients with (1) inadequate imaging evaluation (those diagnosed based on unenhanced MRI or CT alone or without CTA/DSA), (2) a small tumor associated with massive hematoma, and (3) atypical imaging features (heterogeneous signal density/intensity, absent dural tail sign, marked heterogeneous/rim/peripheral enhancement) were more likely to be misdiagnosed. Neurosurgeons and radiologists should be aware of these points and consider HM in the differential diagnoses of traumatic and non-traumatic intracranial hematoma and hemorrhagic neoplasm.

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Ethical approval

This study was approved by the ethics commission of the First Affiliated Hospital of Shantou University Medical College. The requirement for written informed consent

was waived.

Disclosure of interest

The authors report no conflict of interest.

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Figure Legends

Figure 1. Case 4. A 37-year-old woman with meningothelial meningioma associated with intratumoral and subdural hematoma. Axial unenhanced head computed tomography (**a**) and axial T1-weighted imaging (**b**), T2-weighted imaging (**c**), and contrast-enhanced T1-weighted imaging (**d**) at admission. The images show a massive acute falcine subdural hematoma with variable signal density/intensity (*arrow*) that has heterogeneous marked peripheral enhancement and a dural tail sign (*arrow head*).

Figure 2. Case 3. A 53-year-old woman with fibrous meningioma associated with intratumoral hemorrhage. Axial unenhanced head computed tomography (**a**), axial T1-weighted imaging (**b**), T2-weighted imaging (**c**), fluid-attenuated inversion recovery imaging (**d**), and contrast-enhanced T1-weighted imaging (**e**), and sagittal contrast-enhanced T1-weighted imaging (**f**) at admission. The images show mixed acute and subacute pure intratumoral hemorrhage and cystic change with mixed hypo- and hyperdensity/intensity and strong rim enhancement.

Figure 3. Case 6. A 23-year-old woman with fibrous meningioma associated with intratumoral and subdural hemorrhage. (**a**) Axial unenhanced computed tomography shows a regular acute hematoma in the right occipital lobe and subdural hematoma in the tentorium cerebelli. (**b**) Enhanced computed tomography shows clusters of vascular enhancement on the convex surface of the hematoma.

Figure 4. Representative case of a correctly diagnosed hemorrhagic meningioma. A 33-year-old woman with hemorrhagic angioblastic meningioma. Axial T1-weighted imaging (**a)**, axial T2-weighted imaging (**b**), sagittal T2-weighted imaging (**c**), axial contrast-enhanced T1-weighted imaging (**d**), coronal contrast-enhanced T1-weighted imaging (**e**) and sagittal contrast-enhanced T1-weighted imaging (**f**) show a regular tumor (*star*) with intratumoral hemorrhage in the left frontal parafalcine region at admission. The tumor was iso- and hyperintense on T1-weighted images and mixed hypo- and hyperintense on T2-weighted images (*arrow*) with peritumoral cerebral oedema. Contrast-enhanced images show heterogeneous marked enhancement with a dural tail sign (*arrow head*).

Figure 5. Flow chart of study selection for inclusion in the systematic review.

Table 1. Clinical features of 6 patients with an initially misdiagnosed hemorrhagic meningioma

No	Age (yrs),Sex	Symptoms	GCS	Previous History	Consciousness	Op, Srg	Tumor type	Outcome (follow-up)
1	59, M	Headache, blurred vision	13	None	CP	R, I	Fibrous	Morbi, alive, NTR (45 m)
2	51, F	Hemiparesis, semicoma	13	Hypertension	CP	R, II	Anaplastic	Norm, alive, NTR (44 m)
3	53, F	Hemiparesis, drowsy	13	Hypertension, gastritis	CP	R, I	Fibrous	Norm, alive, NTR (51 m)
4	37, F	Headache, hemiparesis	14	None	CP	R, I	Meningothelial	Norm, alive, NTR (42 m)
5	19, F	Headache, drowsy, nausea and vomiting	10	None	UD	R, I	Transitional	Morbi, alive, NTR (76 m)
6	23, F	Headache, nausea and vomiting	11	None	UD	R, I	Fibrous	Morbi, alive, NTR (114 m)

F, female; M, male; yrs, years; GCS, Glasgow Coma Scale; UD, unconscious after deterioration; CP, conscious preoperatively; R, resection of bleeding meningioma and hematoma removal in one stage; Op, operation; Srg, Simpson resection grade I-V; TR, tumor recurrence; NTR, no tumour recurrence; Norm, normal neurological status; morbi, presence of neurological impairments; m, months

Table 2. Radiological features of 6 patients with initially misdiagnosed hemorrhagic meningioma

No	Size (cm)	Location	Tumor shape	Imaging studies	Bleeding type	Imaging findings§		Initial diagnosis			Final diagnosis
						CT	MRI	CT	MRI	CTA /DSA	
1	2.8	Tuberculum sellae	Irregular	CT, CTA, MRI†	ITH,SAH, PTH	Mixed hypo- + hyperdense	Mixed hypo- + hypersignal intense on T1WI and T2WI	Uncertain	?Aneurysm ? Hemorrhagic M	Negative	Fibrous M
2	3.5	Convexity	Irregular	CT, CTA, MRI†	SAH	Isodensity	T1WI: Mixed iso- + hyperintense on T1WI and T2WI	Uncertain	?Metastasis	Negative	Anaplastic M
3	4	Convexity	Regular	CT, CTA, MRI†	ITH	Mixed hypo- + hyperdense	T1WI: iso- + hypo- T2WI: hypo- + hypersignal intense	?Metastasis	?High grade Glioma	Negative	Fibrous M
4	7.4	Parafalx	Irregular	CT, CTA, MRI†	SDH, ITH	Mixed hypo- + hyperdense	T1WI: iso- + hyper- T2WI: hypo- + hypersignal intense	SDH	?Metastasis ? Hemorrhagic M	Negative	Meningothelial M
5	3.7	Fossa cranii posterior	Irregular	CT, DSA	ITH, PTH	Mixed hypo- + hyperdense	NA	Uncertain	NA	Negative	Transitional M
6	2.5	Convexity	Regular	CT, CTA	ITH, SDH	Mixed hypo- + hyperdense	NA	?Vascular anomaly	NA	Negative	Fibrous M

CT, computed tomography; CTA, computed tomography angiography; MRA, magnetic resonance angiography; ITH, intratumoral hemorrhage; PTH, peritumoral hemorrhage; SAH, subarachnoid hemorrhage; SDH, subdural hematoma; T1WI, T1-weighted imaging; T2WI, T2-weighted imaging; NA, not available; M, meningioma

† MRI with and without gadolinium

§ compared with grey matter

Table 3. Clinico-radiological features of previously reported hemorrhagic meningioma patients with delayed diagnosis or initial misdiagnosis

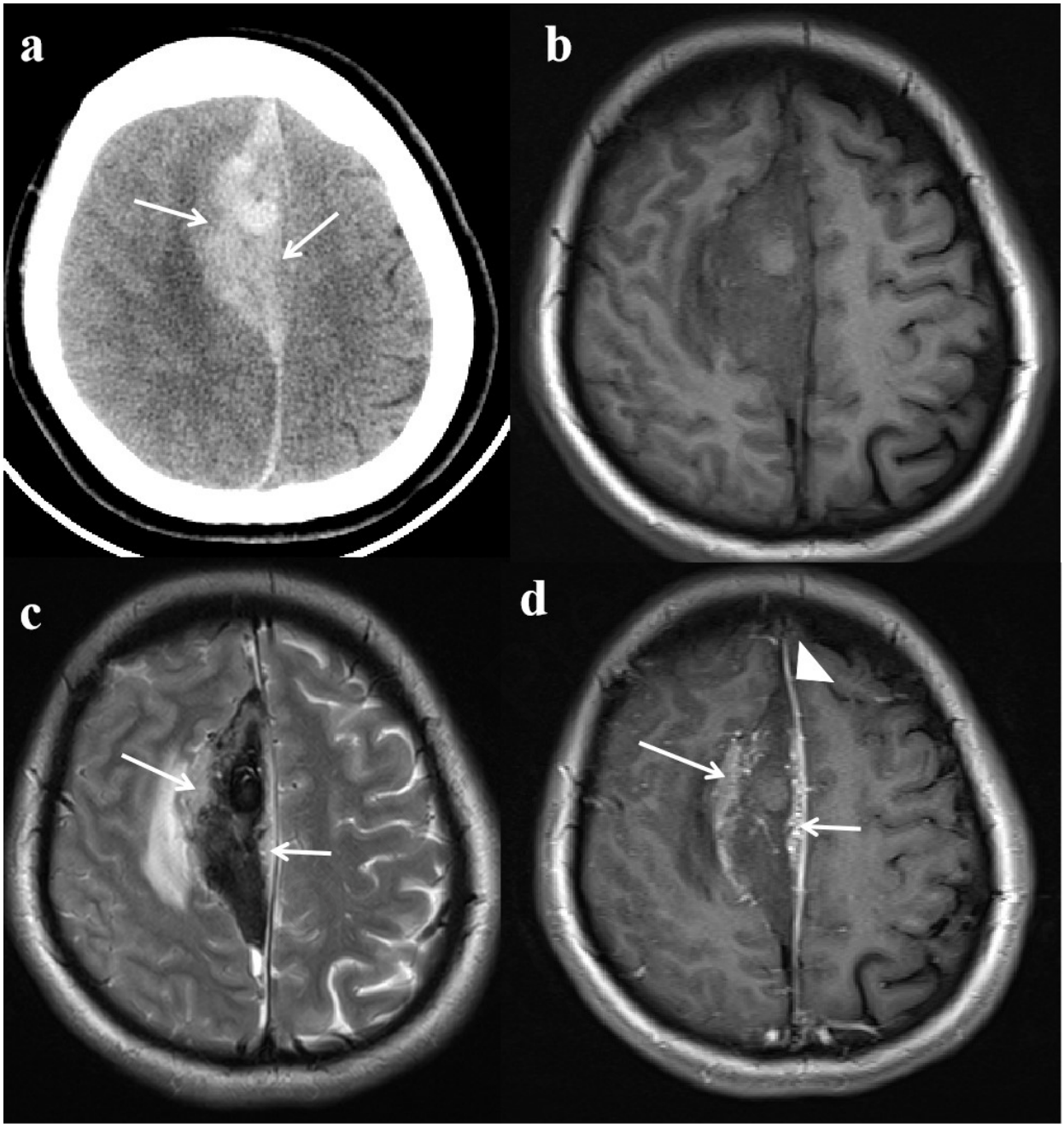
References	Age /Sex	Size (cm)	Bleeding Type	History	Imaging studies	Initial Radiological Diagnosis			Final Diagnosis
						CT	MRI	CTA/DSA	
Chen et al., 1992[10]	79/m	NA	SDH	NA	CT	SDH	NA	NA	Meningothelial M
Kandel et al., 1986[9]	7/F	6	ITH, PTH	None	CT, DSA	Rupture aneurysm	NA	Left MCA aneurysm	Fibrous M & aneurysm
Timothy et al., 1999[11]	64/m	2.5	SDH	Recurrence M	MRI	NA	SDH	NA	Transitional M
Lefranc et al., 2001[4]	68/F	Small[†]	SDH	NA	CT	SDH	NA	NA	Transitional M
Lefranc et al., 2001[4]	85/F	NA	SDH	NA	CT	SDH	NA	NA	Atypical M
Fu et al., 2011[13]	46/F	2.68	IVH	NA	CT, CTA, MRI	Uncertain	Uncertain	Negative	Transitional M
Ki et al., 2012[14]	75/F	5.3	IVH, SDH	Trauma	CT	Hemorrhagic Contusion	NA	NA	Meningothelial M
Alnaami et al., 2013[15]	34/m	3.8	ITH, PTH	None	CT, CTA, MRI[§]	ICH	Hemorrhagic M	Left ACA aneurysm	Meningothelial M & aneurysm
Eljebbouri et al., 2014[17]	51/m	NA	SDH	Trauma	CT	Traumatic SDH	NA	NA	Meningothelial M
Kim et al., 2015[18]	64/F	5	ITH,PTH	Ovarian cancer	CT, MRI[§]	Metastasis	Metastasis	NA	Fibrous M
Di et al., 2014[6]	59/m	NA	SDH	NA	CT	SDH	NA	NA	Angiomatous M
Frič et al.,	68/F	6.7	ITH,	Hypertension	CT, CTA	Uncertain	NA	Negative	Meningothelial M

2016[19]			ICH						
Meguins et al., 2017[20]	65/F	NA	ICH	Hypertension	CT, CTA	Rupture aneurysm	NA	Aneurysm of azygos ACA	Fibrous M & aneurysm
Dang et al., 2020[24]	75/m	6.5	ITH, PTH	Trauma	CT	Traumatic SDH	NA	NA	Angiomatous M
Basil et al., 2018[21]	54/F	2.9	ITH, SAH	NA	CT, CTA, MRI§	Gaint aneurysm	Gaint aneurysm	Gaint aneurysm	Fibrous M
Suzuki et al., 2018[22]	61/F	Small†	SDH, SAH	None	CT, CTA, MRI§	Vascular anomaly	Hemorrhagic M	Negative	Angiomatous M
Schartz et al., 2019[23]	46/m	Small†	IVH	NA	CTA, MRI§	NA	Vascular anomaly	Negative	Atypical M
Sumi et al., 2021[25]	28/F	6.5	IVH, ITH	NA	CT, CTA	Uncertain	NA	Negative	Fibrous M
Alghabban et al., 2020[1]	74/F	2	ITH, SDH	Endometrial cancer	CT, CTA	SDH	NA	Negative	Meningothelial M
Lee et al., 2013[16]	22/F	1.7	ITH, IVH	NA	MRI§	NA	Uncertain	NA	Chordoid M
Chen et al., 2003[12]	74/m	5	ITH	NA	MRI§	NA	Glioma	NA	Malignant M
Miki et al., 2019[5]	91/F	Small†	SDH	Hypertension, diabetes mellitus	CT, MRI	SDH	Hemorrhagic M	NA	atypical/anaplastic M

F, female; m, male; CT, computed tomography; MRI, magnetic resonance imaging; M, meningioma; ITH, intratumoral hemorrhage; IVH, intraventricular hemorrhage; SDH, subdural hematoma; PTH, peritumoral hemorrhage; SAH, subarachnoid hemorrhage; ICH, intracerebral hematoma; NA, not available; ACA, anterior cerebral artery; MCA, middle cerebral artery; CTA, computed tomography angiography; DSA, digital subtraction angiography

† compare with massive hematoma volume

§ enhanced MRI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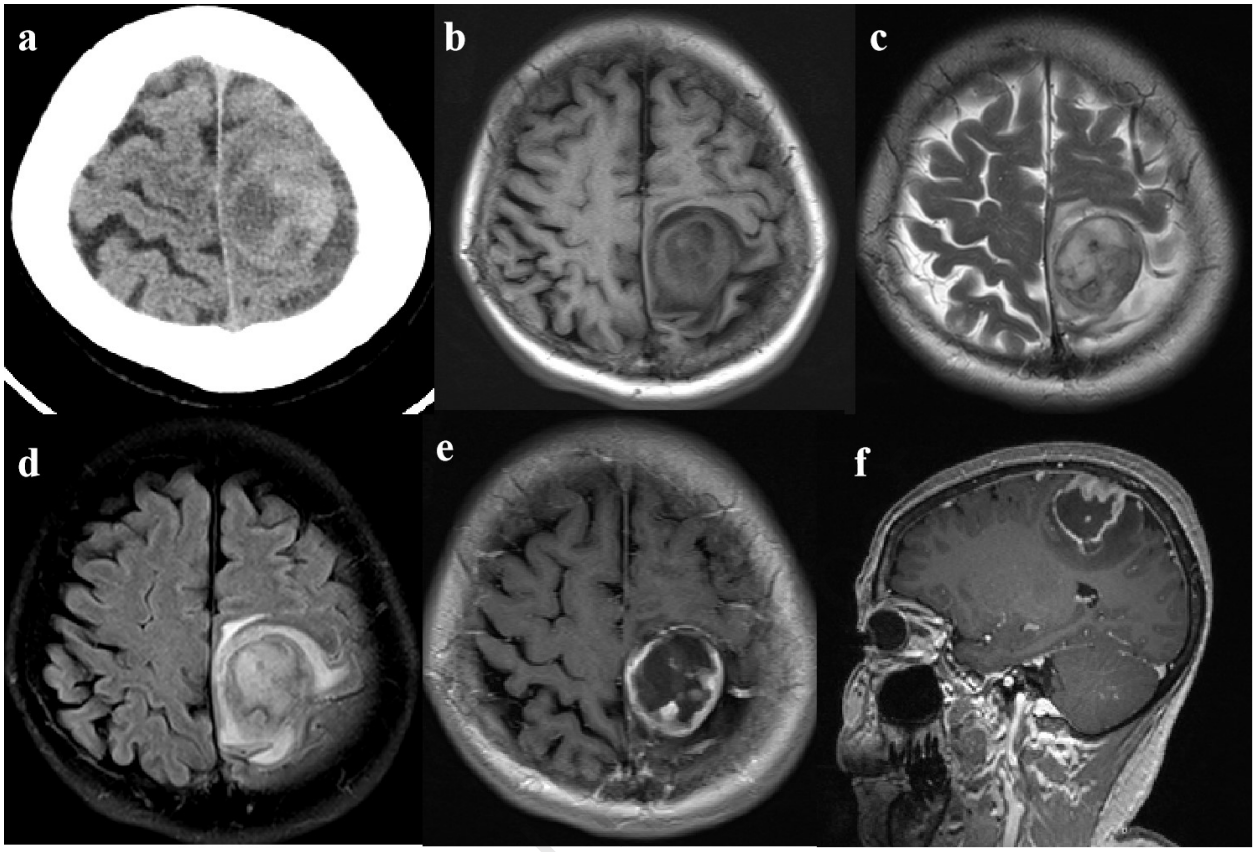

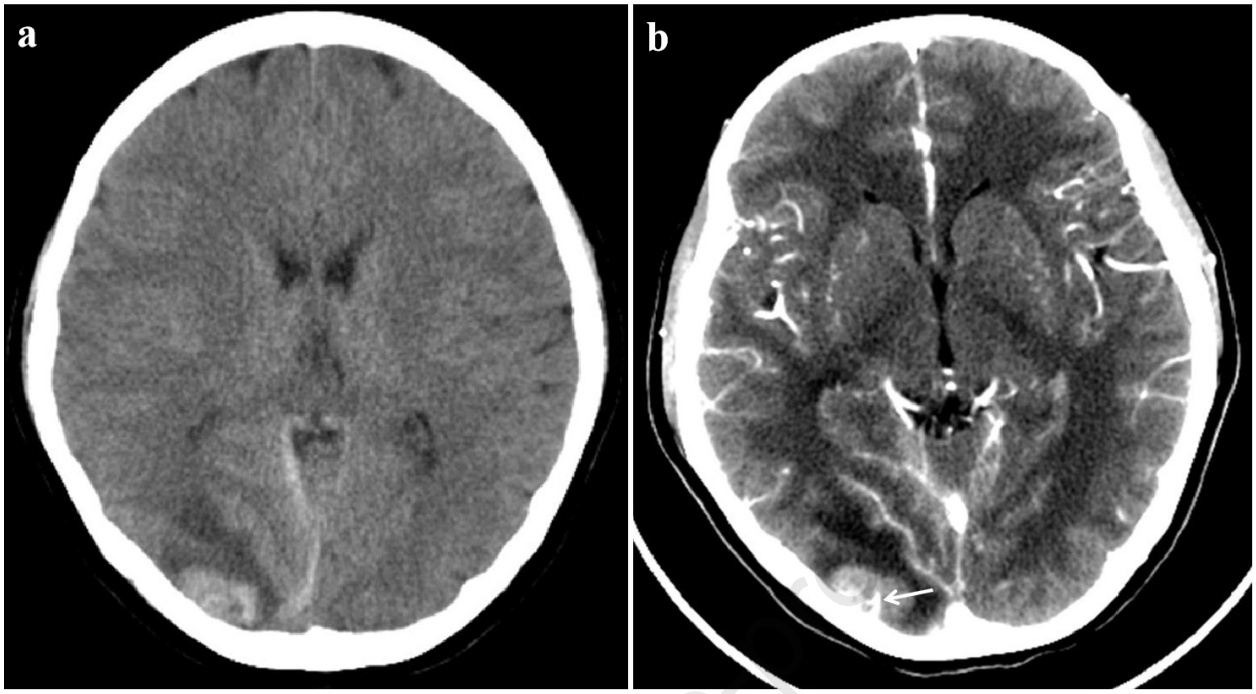

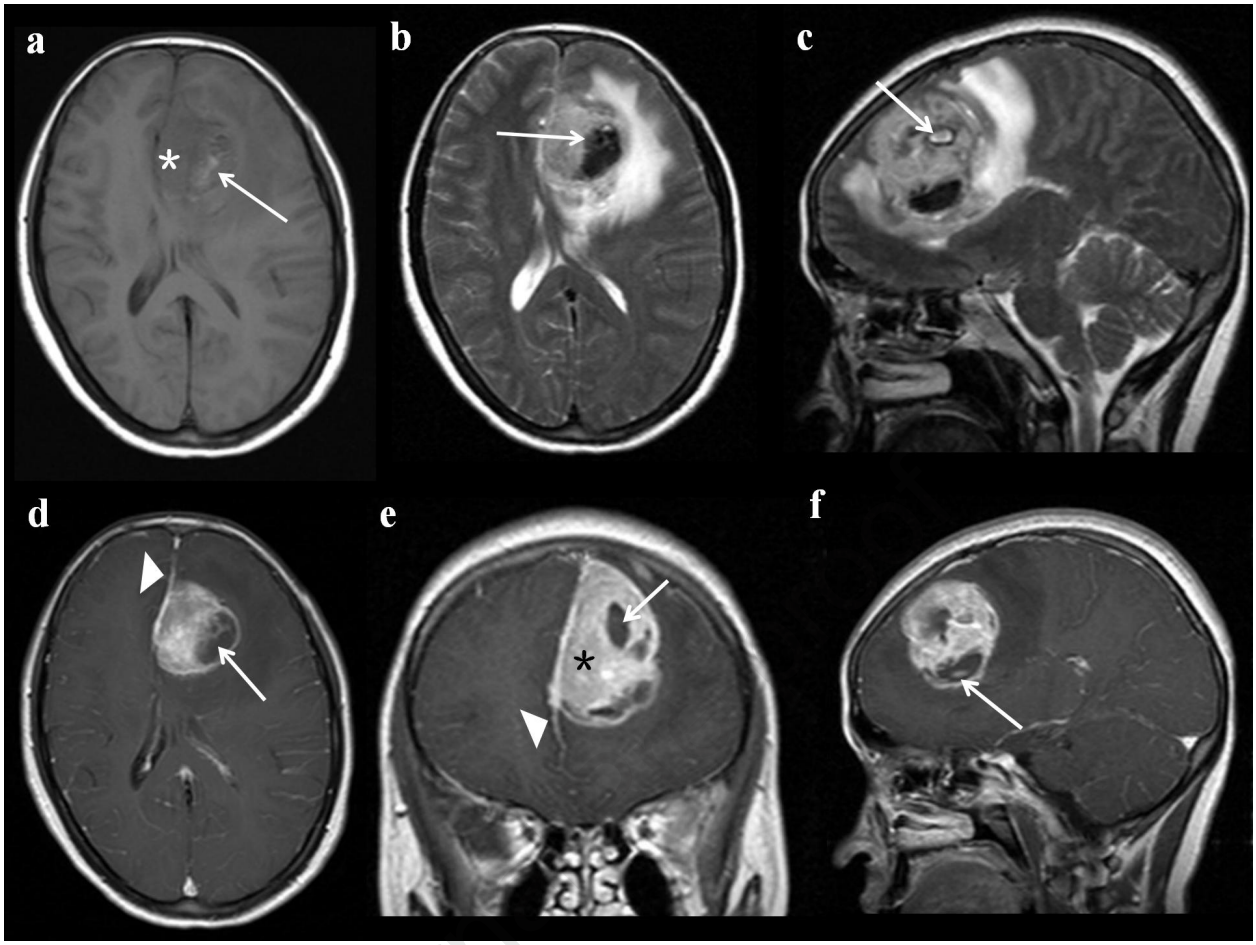

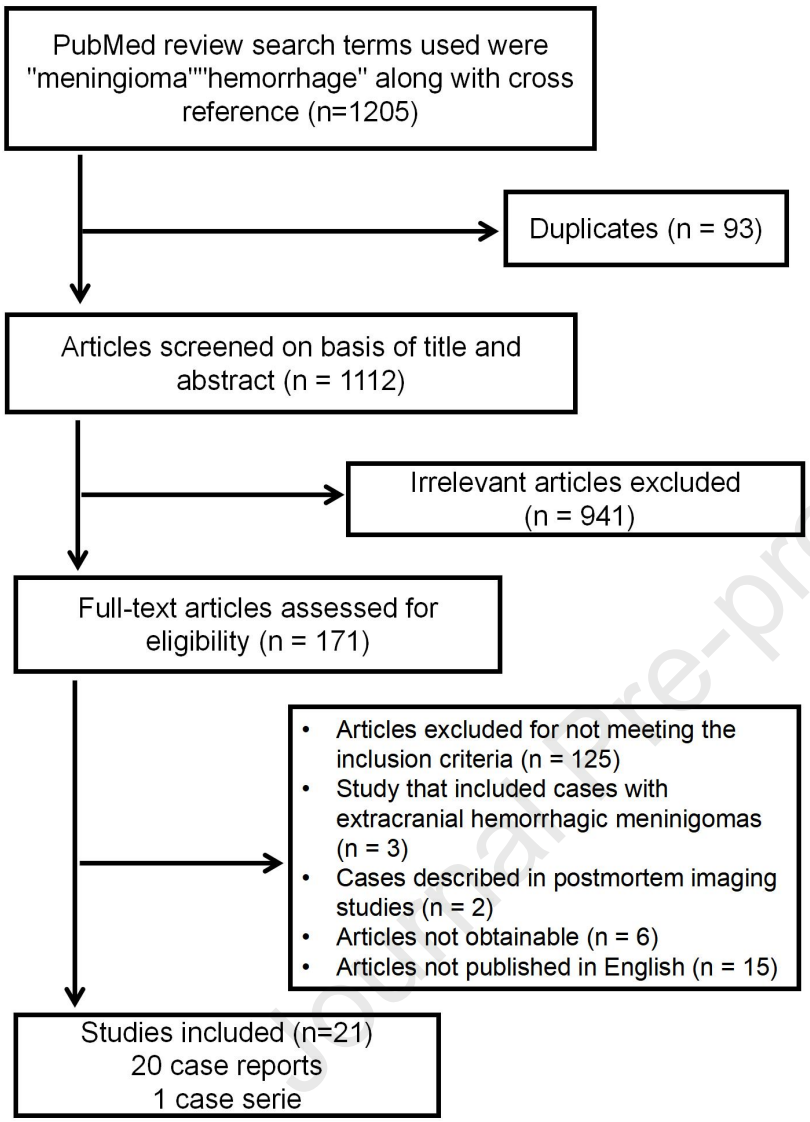

Abbreviations list:

HM, hemorrhagic meningioma

CT, computed tomography

MRI, magnetic resonance imaging

SAH, subarachnoid hemorrhage

SDH, subdural hemorrhage

ITH, intratumoral hemorrhage

PTH, peritumoral hemorrhage

ICH, intracerebral hemorrhage

T1WI, T1-weighted image

T2WI, T2-weighted image

CTA, computed tomography angiography

MRA, magnetic resonance angiogram

DSA, digital subtraction angiogram