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Original Article

Angioarchitecture and Pre-Surgical Embolization of Central Nervous System Solitary Fibrous Tumor/ Hemangiopericytoma

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Objective: Hemangiopericytomas (HPCs) and solitary fibrous tumors (SFTs) have been categorized as the same disease entity, SFT/HPC, since 2016. SFT/HPC is one of the most highly vascularized brain tumors, distinct from meningioma. The angioarchitecture also differs between these tumors. Understanding these differences can help interventionalists perform presurgical embolization more safely and effectively.

Methods: Vascular structures were analyzed in eight patients with central nervous system (CNS) SFT/HPCs, all of whom received presurgical embolization. The type of embolic materials used and the complication rates were compared between the CNS SFT/HPC cases and 39 meningioma cases treated within the same period. Characteristic angiographic features of SFT/HPC were identified, and we present their interpretation and utilization to inform embolization strategies.

Results: Four angiographic features of SFT/HPCs were identified. 1) Persistence of tumor stain and 2) feeders from branches of the internal carotid artery or vertebral artery were observed in all cases, while 3) connecting feeders (highly dilated vessels that originate from branches of other feeder vessels and run along the surface of one tumor compartment to feed another compartment) were observed in five out of eight cases. 4) Finally, an intratumoral arteriovenous shunt was identified in one case. The frequency of liquid embolic material use was significantly higher in SFT/HPC cases than in meningioma cases. No complications were observed in SFT/HPC cases, and all tumors were effectively removed.

Conclusion: The most appropriate presurgical embolization strategies differ between SFT/HPCs and meningiomas depending on the tumor angioarchitecture. A thorough understanding of the vascular anatomy is necessary for safe and effective embolization of SFT/HPCs.

Keywords ▶ solitary fibrous tumor, hemangiopericytoma, embolization

Introduction

As hemangiopericytomas (HPCs) can be found in the meninges, HPC has previously been classified as a subtype of meningeal tumor.[1)] Solitary fibrous tumors (SFTs) are recognized as mesenchymal neoplasms that can arise from soft tissue in any part of the body. These two tumors were considered as separate entities until 2013, when the expression of NAB2–STAT6 fusion proteins was confirmed in SFT.[2)] Subsequently, SFT and HPC were found to share a genomic inversion at the 12q13 locus, which led to the fusion of the NAB2 and STAT6 genes. In the 2016 World Health Organization (WHO) classification of tumors of the central nervous system (CNS),[3)] SFTs and HPCs were combined into one pathological entity, "solitary fibrous tumor/hemangiopericytoma" (SFT/HPC). It is important to recognize that SFT/HPCs are markedly different from meningiomas at the genetic level. Differences in genetic background affect the characteristics of vascular networks in and around tumors, meaning that different embolization strategies are appropriate in distinct tumor types. In this article, we assessed the angioarchitecture of CNS SFT/

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HPCs and discussed the appropriate presurgical embolization strategy compared to that for meningiomas.

Materials and Methods

All patients who had a histological diagnosis of SFT/HPC or meningioma and received presurgical embolization between January 2011 and March 2020 at the Department of Neurosurgery where the corresponding author belongs to were considered for inclusion in this study. One patient who had an SFT/HPC located within the posterior region of the neck adjacent to the vertebral artery (VA) was excluded from the analysis, because the tumor was located outside the CNS. Angiographic data, embolization methods, and the results of presurgical embolization and surgery were assessed for all other patients. For the analysis of embolization methods, we evaluated the type of embolic materials used and the number and characteristics of embolized feeders. This study was approved by the Institutional Review Board of Keio University, School of Medicine, with the approved number 20200044.

Embolization strategy

All patients who were not allergic to contrast media and did not have renal insufficiency underwent gadolinium (Gd)-enhanced MRI scanning to evaluate the precise location and shape of the tumor, as well as contrast-enhanced CT angiography to evaluate the tumor vascularity. When the tumor vascularity was judged to be high, catheter-based angiography with or without presurgical embolization was performed. In Japan, the only embolization agents covered by health insurance for intracranial or spinal tumor embolization are tris-acryl gelatin microspheres (Embosphere; BioSphere Medical, S.A., Roissy, France) and coils. Therefore, our strategy for presurgical embolization prioritized the use of microspheres and coils. The use of *N*-butyl-2-cyanoacrylate (NBCA) or other liquid materials was limited to cases when the risk/benefit analysis clearly favored their use.

All embolization procedures were conducted under local anesthesia. The common femoral artery was punctured, and a 5–6 French gauge (Fr) introducer sheath was inserted. Systemic heparinization was performed to maintain activated clotting time between 250 and 300 seconds. After control angiography, a 5–6 Fr guiding catheter was introduced into the internal carotid artery (ICA) or external carotid artery (ECA), or the VA. Then a microcatheter was advanced into the tumor feeding artery as close as possible to the tumor. When it was recognized that the feeders could potentially communicate with pial vessels or feed the cranial nerves, a provocation test using xylocaine was performed. If the provocation test elicited neurological symptoms, large particles of a diameter greater than 500 μm or coils were used. If the test was negative and it was considered that liquid embolic materials would be more appropriate to devascularize the tumor with minimal risk, NBCA was selected. The microcatheter preferentially used in this study was the flow-directed catheter (Marathon; Medtronic, Dublin, Ireland).

Results

Of the 79 patients who underwent presurgical embolization at the study center during the study period, eight had a histological diagnosis of SFT/HPC and 39 had a histological diagnosis of meningioma.

Angioarchitectural features of SFT/HPCs

We observed the following four angiographic features in SFT/HPCs:

1. Persistence of tumor stain: All eight SFT/HPC tumors exhibited not only marked tumor stain after the injection of contrast medium but also the retention of contrast medium until the late venous phase (**Fig. 1C**: large arrow).
2. Feeders from branches of the ICA and VA: All eight SFT/HPC tumors appeared on MRI as meningeal tumors attached to the dura mater with ECA feeders. Additionally, all cases also had ICA/VA feeders, including true pial feeders (**Fig. 2**) and dural branches from the ICA/VA.
3. Dilated connecting feeders: Five out of the eight tumors exhibited significantly dilated vessels that originated not from the main trunks of the ICA, ECA, or VA but from branches of the other feeder vessels; these were found to run along the surface of one compartment of the tumor and feed another compartment. These were termed "dilated connecting feeders" (**Fig. 1A** and **1B**: thin arrow).
4. Intratumoral arteriovenous (AV) shunt: One case showed early filling of a venous sinus with contrast medium draining from the tumor (**Fig. 3**), indicating the presence of an AV shunt within the tumor.

Embolic materials and complication rates

All eight cases of SFT/HPC were hypervascular tumors. In these tumors, a total of 22 feeders were embolized (a mean of 2.8 vessels per case). NBCA was used in 14 feeders (63.6%), while particles or coils were used in eight feeders. Maximum and minimum concentration of NBCA were

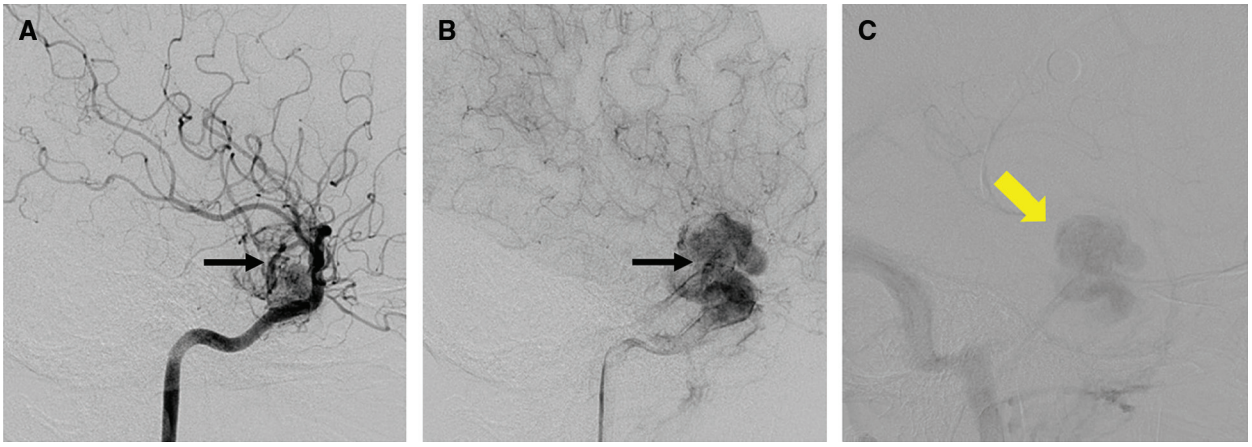

Fig. 1 Right internal carotid angiogram in lateral view. Tumor stain around cavernous sinus retains until the late phase (large arrow) with a dilated feeder connecting two compartments of the tumor (arrow). (**A**) Arterial phase. (**B**) Early venous phase. (**C**) Late venous phase.

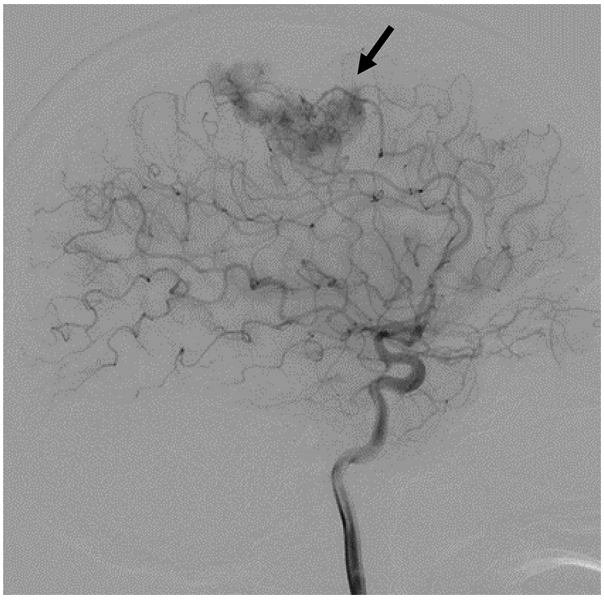

Fig. 2 Right internal carotid angiogram in lateral view. True pial feeders are seen in parasagittal lesion (arrow).

50% and 20%, respectively. There were nine ICA/VA feeders in this study, among which eight feeders (89%) were embolized with NBCA. Although the use of the provocation test was one of our treatment strategies, there were no cases in which choice of embolic materials was changed after provocation tests. In the 39 cases with meningiomas, a total of 91 vessels were embolized (mean: 2.3 vessels per case), and the frequency of NBCA injection was significantly lower than in SFT/HPC cases (17 vessels, 18.7%; $p < 0.001$, chi-square test: **Table 1**). No complications were observed in the embolization of SFT/HPCs, whereas two cases (5%) of meningioma experienced complications; however, this difference was not significant. All tumors were removed as planned adequately and without massive hemorrhage during surgery.

Case description

A 53-year-old female presented to her local clinic with dysphagia; a mass in her pharynx was diagnosed, and she was subsequently referred to our hospital. Gd-enhanced MRI revealed a dumbbell-shaped mass in the spinal canal extending ventrally through the intervertebral foramen into the pharynx (**Fig. 4A** and **4B**). Biopsy was performed, and the mass was diagnosed as an SFT. CT angiography showed that the mass was hypervascular, so presurgical embolization was indicated. Digital subtraction angiography (DSA) revealed a multilobulated mass in the cervical spinal canal with marked contrast agent retention. The feeders came mainly from the VA (**Fig. 4D**), though the ascending pharyngeal artery (**Fig. 4F**) and the ECA also contributed feeder vessels. Some dilated connecting feeders were observed supplying multiple portions of the tumor. A 6 Fr guiding catheter (Optimo; Tokai Medical, Aichi, Japan) was inserted into the left VA, and a microcatheter was then used to cannulate the direct feeder from the left VA. As the tumor was compressing the spinal cord and bulging into the airway, there was a concern that post-embolization intratumoral bleeding could induce a critical situation such as tetraparesis or airway obstruction. Particle embolization in some hypervascular tumors[4] has been associated with a higher risk of postoperative tumor swelling and bleeding; therefore, liquid embolization with NBCA was judged to be the most effective and safe option. In order to avoid reflux of NBCA into the intracranial vessels when NBCA was accidentally migrated into the VA, the proximal balloon of the

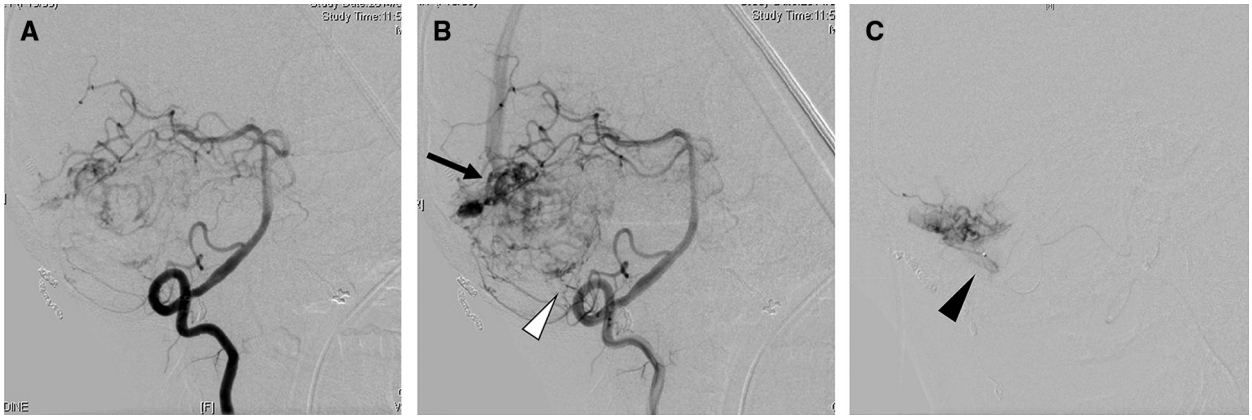

Fig. 3 Left vertebral angiogram in oblique view shows early venous filling of superior sagittal sinus (arrow) indicating AV shunt in the tumor. (**A**) Early arterial phase. (**B**) Late arterial phase. (**C**) Injection from the microcatheter advancing just proximal to the tumor. White arrowhead in (**B**) indicates the same site of black arrowhead in (**C**). AV: arteriovenous

Table 1 The number of vessels in which each embolic material was used in each tumor type

	Particle/coil	NBCA
Meningioma	74 (81.3%)	17 (18.7%)
SFT/HPC	8 (36.4%)	14 (63.6%)*

*p <0.001. HPC: hemangiopericytoma; NBCA: *N*-butyl-2-cyanoacrylate; SFT: solitary fibrous tumor

guiding catheter was inflated, making reversed flow in the VA by opening chamber of the proximal side of the catheter. Then 0.2 ml of 40% NBCA was injected from the VA feeder to occlude the connecting feeders and tumor (**Fig. 4E**). Subsequently, several feeder branches of the left VA to the tumor and the main trunk of the VA were occluded using coils, until tumor stain from VA injection was no longer observed. After this, tumor stain was still observed from a neuromeningeal branch of the ascending pharyngeal artery that passed through the hypoglossal canal to the anterior spinal canal (**Fig. 4F**). This vessel was dilated within the spinal canal; the microcatheter could thus reach just proximal to the attachment of the meningeal portion of the tumor. This vessel was also embolized using 0.2 ml of 40% NBCA (**Fig. 4G**). After this, the tumor was successfully devascularized, and complete resection was achieved (**Fig. 4C**).

Discussion

It is widely recognized that SFT/HPC is one of the most highly vascularized types of tumor in the CNS. Massive intraoperative bleeding from the tumor can therefore make gross total removal difficult. As the rate of complete resection is negatively correlated with local recurrence rate,[5] presurgical embolization plays an important role in managing these tumors.[6] However, SFT/HPCs are rare, accounting for only 1% of intracranial tumors.[7] Thus, there is a lack of knowledge about their angioarchitecture and the best embolization strategies. Some papers have outlined the angiographic features of SFT/HPCs in terms of feeder vessels and tumor staining. However, detailed descriptions of the tumor angioarchitecture and data to support safe and effective embolization are still lacking. We, therefore, present our observations on this tumor to help inform embolization strategies.

Angioarchitecture of SFT/HPCs

In a review of 189 cases of SFT/HPC,[8] 22 cases were evaluated by angiography. A neoplastic aneurysm was found in two cases, tumor stain in 12, and ICA feeders in nine. Sibtain et al. studied the angiographic features of meningeal HPC in 2007 and made the following findings: 1) dual supply from the ICA or VA as well as the ECA, with the dominant supply being from the ICA rather than the ECA branches as seen in meningiomas; (2) a myriad of corkscrew vessels arising from a main feeder within the tumor; (3) a dense, fluffy, long-lasting tumor stain, in contrast to the "sunburst" pattern seen with meningiomas; and (4) a lack of early draining veins.[9] However, this paper defined HPC as a type of tumor different from SFT; thus, these statements may require further clarification and modification after the 2016 WHO classification.

In our study, we repeatedly observed two of the features described by Sibtain et al. One was long-lasting tumor stain retention; we found this in all cases. Tumor stain retention might reflect a dilated vascular channel, which implies increased intratumoral vascular pressure caused by insufficient drainage from tumor vessels in relation to the

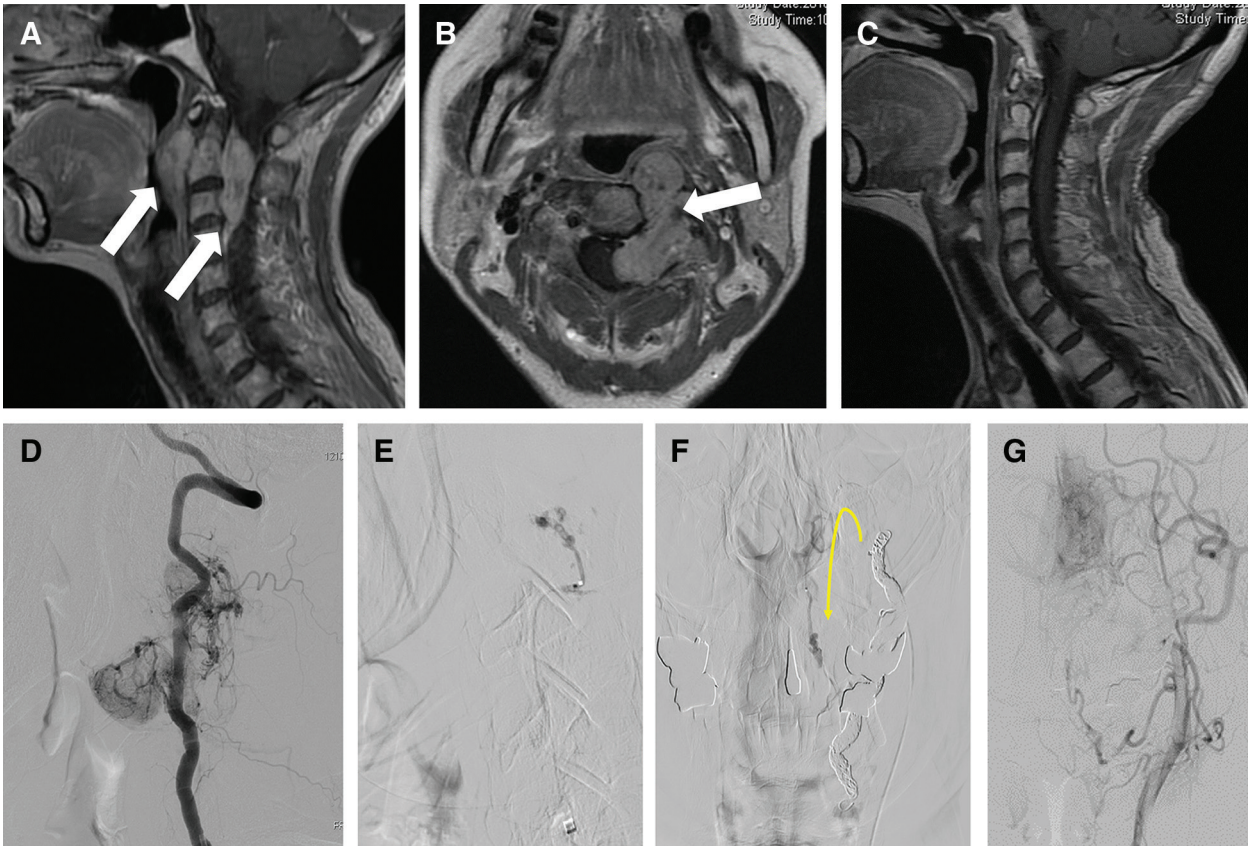

Fig. 4 (**A**) Gd-enhanced MRI in sagittal plane. The tumor is extending into spinal canal and pharynx (white arrows). (**B**) Gd-enhanced MRI in the axial plane. Dumbbell-shaped tumor is seen (white arrow). (**C**) Postoperative MRI. Tumor is completely removed. (**D**) Left vertebral angiogram in lateral view, showing tumor stain in multiple compartments. (**E**) NBCA is injected into the dilated connecting the feeder and the tumor. (**F**) The microcatheter is inserted into the dilated feeders in the spinal canal (thin arrow) from the ascending pharyngeal artery through the hypoglossal canal. (**G**) Tumor stain disappears completely. Gd: gadolinium; NBCA: *N*-butyl-2-cyanoacrylate

high supply from feeders. Hence, this angiographic feature definitely suggests the need for extensive embolization.

The second feature was ICA/VA feeders, which was also found in all cases. Embolization from ICA/VA feeders is sometimes difficult and withdrawn when the true pial feeders supply deep-seated tumors or tumors in eloquent areas (**Fig. 2**). As reflux of the embolic materials toward the ICA/VA must be avoided, extensive liquid embolization sometimes raises substantial risk. The tip of the microcatheter should be placed as close to the tumor as possible in order to avoid unnecessary brain infarction (**Fig. 3B** and **3C**).

In our study, we also observed two other features that have not been previously described. One was "dilated connecting feeders," which originate not from the main trunks of the ICA, VA, or ECA but from their branches, and run along the surface of one compartment of the tumor to feed another compartment. We found these vessels in five out of eight tumors. SFT/HPCs are sometimes multilobulated, while most meningiomas grow with fewer compartments. Dilated connecting vessels can develop in hypervascularized and multilobulated tumors when one compartment of the tumor recruits a large amount of vessels from adjacent compartments by the secretion of angiogenic factors around the tumor through activation of the vascular endothelial growth factor (VEGF) pathway.[10] The existence of connecting vessels raises the necessity to perform not only "intratumoral embolization of one compartment of the tumor" but also "embolization of multiple compartments of the tumor by occluding the connecting vessels." In order to achieve effective embolization of multiple compartments, liquid embolic materials appear to be superior to coils or particles in terms of penetration into the connecting feeders.

The other new finding that we observed in this study was the existence of an "intratumoral AV shunt." We observed an AV shunt in only one case of SFT/HPC. Thus, this feature is not universally found in these tumors. However, a previous study has reported that particle embolization has caused severe cerebral infarction in certain cases

of pleural SFT/HPC, and an intratumoral AV shunt was suspected to have enabled the embolic materials to pass into the brain.[11] When an AV shunt is observed in SFT/HPCs, we believe that particle embolization is dangerous because the particles are invisible on DSA images and can easily migrate into draining veins. On the contrary, proximal coil embolization cannot sufficiently decrease the flow within the tumor. Therefore, liquid embolic materials are recommended in these cases.

Embolization technique

As described above, SFT/HPC has several characteristic vascular features. Detailed analysis of the specific angioarchitecture using 3D DSA or cone-beam CT in addition to conventional 2D DSA is necessary before embolization. In terms of technical considerations, flow-guided or flow-directed microcatheters with softer tips can be advanced closer to the tumor; this sometimes requires cannulation of the microcatheter into the connecting vessels. In many SFT/HPC cases, feeders close to the tumor are dilated, which allows the microcatheter to advance closer than they do in other tumors. In order to advance the microcatheter, an intermediate or distal access catheter might be useful. The decision as to whether pial feeders should be occluded can be important in constructing an embolization strategy.

If the catheter is successfully advanced just proximal to the tumor, liquid embolic materials such as Onyx or NBCA are safe and effective in many cases. Liquid embolic materials are likely to be a safer choice in cases with intratumoral AV shunts, but extensive intratumoral injection through the AV shunts leading to occlusion of drainage vein in these cases might be dangerous to elicit postoperative bleeding as occlusion of venous side of AVM. When embolizing with NBCA, the question of how far to penetrate into the tumor or connecting feeders depends on the vascular structure, which should be determined before deciding the concentration of the mixture of NBCA and lipiodol. We prefer relatively high concentration (40% to 50%) of NBCA in cases with intratumoral AV shunts for safety and medium to low concentration (20% to 33%) of NBCA in cases without shunts for efficacy. Hanak et al.[5] described a trans-tumoral embolization technique that uses Onyx introduced from ECA feeders, penetrating through the tumor vascular bed to the entrance of pial feeders. Although the use of liquid embolic materials in brain tumors is not currently permitted in Japan, this technique might in the near future be an appropriate solution for tumors that have both ECA and ICA/VA feeders.

Limitations of this study

This study has certain limitations. First, this report is based on results from only a small number of cases. Second, the decision to use liquid embolic materials was based on subjective judgment rather than strict guidelines. However, no SFT/HPC cases developed complications after the use of NBCA, and all cases of SFT/HPCs were treated successfully. Therefore, we believe that our analysis can provide value.

Conclusion

The angioarchitecture of SFT/HPCs is distinctly different from that of meningiomas. Detailed evaluation before embolization, the use of appropriate devices to reach the tumor, and the choice of appropriate embolic materials such as liquid embolics are required for successful treatment. With a thorough knowledge of the angioarchitecture of these tumors, analysis tailored to each case, and careful performance of embolization, interventionalists can safely and reliably achieve satisfactory results.

Disclosure Statement

There is no conflict of interest for the first author and coauthors.

References

1) Begg CF, Garret R: Hemangiopericytoma occurring in the meninges: case report. *Cancer* 1954; 7: 602–606.
2) Robinson DR, Wu YM, Kalyana-Sundaram S, et al: Identification of recurrent NAB2-STAT6 gene fusions in solitary fibrous tumor by integrative sequencing. *Nat Genet* 2013; 45: 180–185.
3) Louis DN, Perry A, Reifenberger G, et al: The 2016 World Health Organization classification of tumors of the central nervous system: a summary. *Acta Neuropathol* 2016; 131: 803–820.
4) Cornelius JF, Saint-Maurice JP, Bresson D, et al: Hemorrhage after particle embolization of hemangioblastomas: comparison of outcomes in spinal and cerebellar lesions. *J Neurosurg* 2007; 106: 994–998.
5) Hanak BW, Haussen DC, Ambekar S, et al: Preoperative embolization of intracranial hemangiopericytomas: case series and introduction of the transtumoral embolization technique. *J Neurointerv Surg* 2016; 8: 1084–1094.
6) Matsushige T, Nakaoka M, Yahara K, et al: Single-stage operation for a giant haemangiopericytoma following

intracranial feeder embolization. *J Clin Neurosci* 2007; 14: 162–167.

7) Akiyama T, Yoshida K, Horiguchi T, et al: Management of hemangiopericytoma. In: M.A. Hayat, editor. Tumors of the Central Nervous System. Springer Netherlands, 2013, 31–39.
8) Fargen KM, Opalach KJ, Wakefield D, et al: The central nervous system solitary fibrous tumor: a review of clinical, imaging and pathologic findings among all reported cases from 1996 to 2010. *Clin Neurol Neurosurg* 2011; 113: 703–710.
9) Sibtain NA, Butt S, Connor SE: Imaging features of central nervous system haemangiopericytomas. *Eur Radiol* 2007; 17: 1685–1693.
10) Park MS, Ravi V, Araujo DM: Inhibiting the VEGF-VEGFR pathway in angiosarcoma, epithelioid hemangioendothelioma, and hemangiopericytoma/solitary fibrous tumor. *Curr Opin Oncol* 2010; 22: 351–355.
11) Inagawa S, Sato T, Koike T, et al: Another case of erratic brain embolism after particle embolization for a giant intrathoracic solitary fibrous tumor. *Cardiovasc Intervent Radiol* 2018; 41: 1448–1450.