ORIGINAL RESEARCH

Embolization of posterior fossa meningiomas supplied with meningohypophyseal trunk by using *n*-BCA and dual balloon protection

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ABSTRACT

BACKGROUND AND PURPOSE: Efficacy of tumor embolization for posterior fossa meningioma is controversial due to the lack of adequate embolization for dangerous feeders. Of these, a meningohypophyseal trunk (MHT) has high therapeutic value despite the high risks associated with embolization.

MATERIALS AND METHODS: To analyze the utility of preoperative MHT embolization for posterior fossa meningiomas using *n*-BCA with dual balloon protection, a single center retrospective record review was performed on eight consecutive patients who underwent preoperative tumor embolization via the MHT for posterior fossa meningiomas between 2020 and 2024.

RESULTS: All patients successfully embolized the MHT using *n*-BCA. Complete obliteration was achieved in five cases, which is related to the tentorial artery alone as the feeding vessel. None of the patients had cerebral infarction associated with distal embolization. One patient experienced worsening of preoperatively observed abducens nerve palsy due to cranial nerve ischemia. Gross total resection was achieved in seven of eight cases. The mean estimated blood loss during surgical resection was 186 mL (range, 39–392 mL). The mean operative time was 431 min (range, 317-767 min).

CONCLUSIONS: The MHT embolization of posterior fossa meningiomas by using *n*-BCA is technically feasible with a high success rate and an acceptable complication rate.

ABBREVIATIONS: MHT=meningohypophyseal trunk; ILT=inferolateral trunk; CPA=Cerebellopontine angle; BGC=balloon guide catheter; PVA=polyvinyl alcohol; GTR=Gross Total Resection; CN=Cranial nerve.

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Disclosure of potential conflicts of interest should be included here.

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SUMMARY SECTION

PREVIOUS LITERATURE: Efficacy of tumor embolization for posterior fossa meningioma is controversial due to the lack of adequate embolization for dangerous feeders. Of these, a meningohypophyseal trunk (MHT) has high therapeutic value despite the high risks associated with embolization.

KEY FINDINGS: All patients successfully embolized the MHT using *n*-BCA without cerebral infarction. One patient experienced worsening of abducens nerve palsy. Gross total resection was achieved in seven cases. The mean blood loss during surgery was 186 mL (range, 39–392 mL). The mean operative time was 431 min (range, 317-767 min).

KNOWLEDGE ADVANCEMENT: The MHT embolization of posterior fossa meningiomas by using *n*-BCA is technically feasible with a high success rate and an acceptable complication rate.

INTRODUCTION

In recent years, meta-analyses of case series and matched cohorts have shown that preoperative embolization for meningiomas is effective in reducing perioperative complications, improving postoperative functional outcomes, and prolonging the time to recurrence.[1-4] However, the results for skull base meningiomas are still controversial and unsatisfactory: a systematic review showed a lower rate of adequate embolization of the feeding vessels (17%) and a higher complication rate due to the preoperative embolization (12%) than non-skull base meningioma.[5] The main reason may be the lack of adequate embolization of dangerous feeders such as the ascending pharyngeal artery, the meningohypophyseal and inferolateral trunks (MHT and ILT), the artery of the foramen rotundum, the accessory

meningeal artery, and the anterior / petrosal branch of the middle meningeal artery.[5] In particular, MHT and ILT originating from the ICA make insertion of a microcatheter difficult, such as the branching angle, curvature and vessel diameter. The risk of cerebral infarction and cranial nerve impairment must also be considered. On the other hand, from a surgical approach (i.e. retrosigmoid / transpetrosal), it is desirable for the surgeon if preoperative closure can be achieved because MHT and ILT are the deepest tumor feeding vessels and devascularization must be achieved at the end of surgery.[6] The MHT, as the feeding vessel of the meningioma, was embolized with particulate in previous reports. However, the difficulty of navigating the particle-compatible microcatheter can decrease the success rate of endovascular devascularization preoperatively. We hypothesized that the use of smaller diameter microcatheters would increase the probability of introducing the microcatheter into the MHT. We performed embolization of the MHT using *n*-BCA for posterior fossa meningiomas. We aimed to review our series and discuss safety and technical tips for the procedure from an anatomical perspective.

MATERIALS AND METHODS

study design

We retrospectively reviewed consecutive patients who underwent preoperative tumor embolization via MHT for posterior fossa meningiomas at our institution between September 2020 and January 2024. Baseline data on the patients were collected, including age and sex, maximum tumor size, location, and venous sinus invasion of the tumor. Details of the anatomical character of MHT were evaluated, including the vessel size and branching angle based on 3-dimensional rotational angiography. Based on cone-beam CT, we evaluated whether the feeding vessel was a tentorial artery, a dorsal meningeal artery, or both. In addition, procedural outcomes of the embolization were collected, including technical success, complete or incomplete obstruction of the MHT, and complications including cerebral infarction and cranial nerve impairment. Finally, surgical variables were collected, including estimated blood loss, gross total resection of the tumor, and operative time. This study was approved by our institutional review board. All patients provided written informed consent for treatment, and we applied an opt-out approach for participation. This study has been reported in accordance with the Strengthening the Reporting of Observational Studies in Epidemiology Statement.[7]

Embolization procedure

All patients underwent angiography before endovascular treatment, and neurosurgeons and neurointerventionists discussed the decision to perform preoperative embolization and the goals of the procedure. Embolization was then performed under general anesthesia one or two days before resection. An 8F balloon guide catheter was advanced to the internal carotid artery via the transfemoral approach. A 3.2F distal access catheter was advanced to the petrous segment of the ICA from the guiding catheter. For embolization, a 1.3F DeFrictor（Medico's Hirata）soft microcatheter was navigated to the MHT over a CHIKAI X10 soft microwire（Asahi Intech）. The MHT typically arises from the posterior vertical cavernous segment of the ICA, and runs almost inverted against the ICA. Further, due to its being thin and bent, it is difficult to catheterize. Therefore, after the microguidewire was inserted into the MHT, we used a balloon catheter to fix the microguidewire to the ICA wall to prevent the microguidewire from deviating into the distal ICA. The balloon catheter is left dilated, we followed the tip of the microcatheter to the origin of the MHT, and carefully inserted the microguidewire more distally, and the microcatheter was advanced to the depth of the MHT（Figure 1）. After super selective angiography to verify the catheter's appropriate position

and lack of dangerous anastomose leading to cerebral infarction, the embolization was performed using *n*-BCA（B-braun Aesculap) diluted in 12.5- to 33%. Before *n*-BCA injection, both the balloon guide catheter and balloon catheter were inflated. We first dilate the BGC, and then dilated the balloon catheter to prevent the distal migration of injected glue into the ICA（Figure 1）. After the *n*-BCA injection, the DeFrictor microcatheter was removed followed by deflating the balloon catheter. Aspiration from the balloon guide catheter was performed using a 20ml syringe at least twice. Finally, the BGC was deflated. At the end of the embolization, conventional angiography and cone-beam CT were performed to confirm no evidence of obvious cerebral infarction and or intracranial hemorrhage.

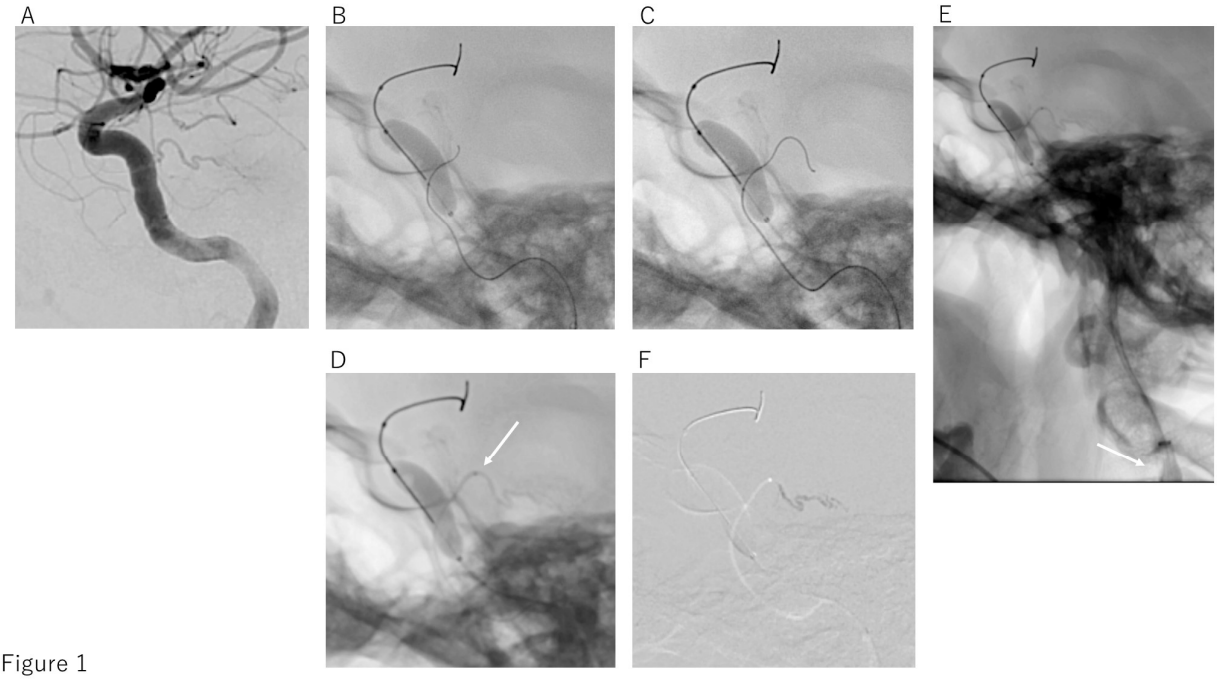

Figure 1

FIG 1. Internal carotid angiogram (lateral view) showed supply to the tumor from the enlarged MHT（A）. After the CHIKAI X10 microguidewire was inserted into the MHT, Scepter C balloon catheter was inflated to fix the CHIKAI X10 to the ICA wall to prevent it from deviating into the distal ICA（B）. The Scepter C balloon catheter was left dilated, and the tip of the DeFrictor nano microcatheter was advanced to the MHT origin. We then carefully inserted the CHIKAI X10 to the depth of the MHT(C). (Superselective angiography via the DeFricter nano) White arrow shows fluoro marker located 5mm proximal to the tip of microcatheter. The catheter tip was non-braded for 5 mm from the tip to provide flexibility(D). Both the balloon guide catheter (white arrow) and balloon catheter were inflated to prevent the distal migration of injected glue into the ICA (E). 25% *n*-BCA was injected for feeder occlusion (F).

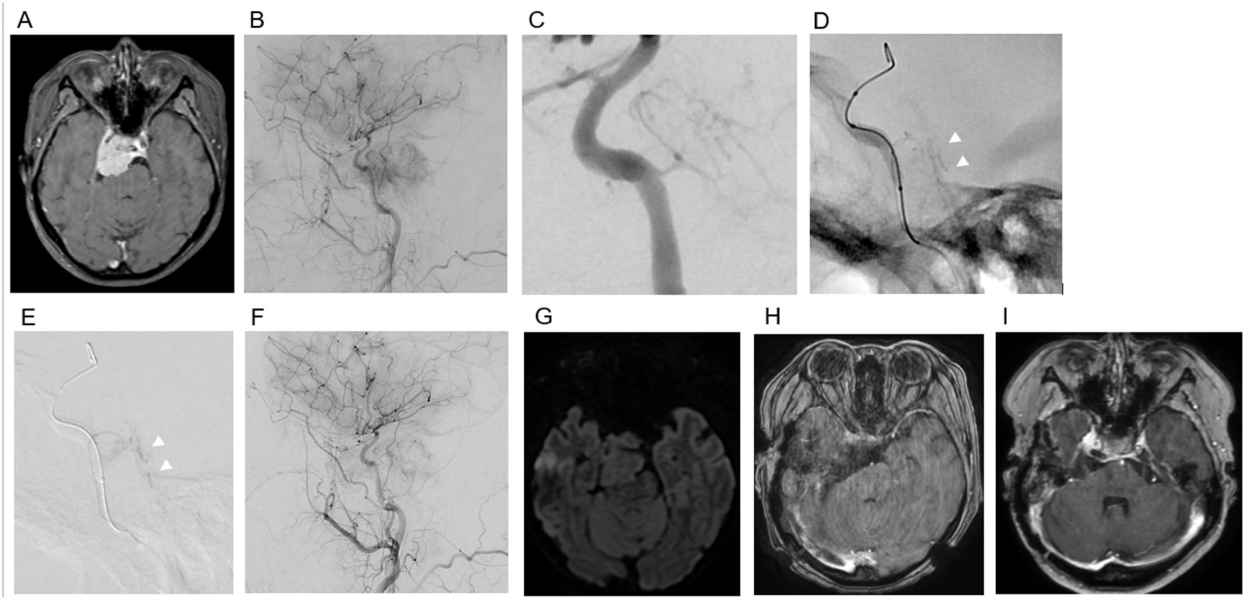

FIG 2. Adult patient with petroclival meningioma on Gd-T1WI image (A). Right common carotid angiogram (lateral view) showed supply to the tumor from the enlarged MHT (B). Both the tentorial artery and the dorsal meningeal artery were feeding vessels (C). 12.5% *n*-BCA penetrated into the dural attachment of the tumor (arrow heads) via the dorsal meningeal artery (D, E) . Postprocedural angiogram showed a partial obliteration of the feeding vessels (F). Postprocedural diffusion weighted image showed no evidence of intra-tumoral ischemia and cerebral infarction (G). Postoperative Gd-T1WI image showed a partial removal of the tumor (H). The nine-month follow-up Gd-T1WI showed a small recurrence on the wall of the right cavernous sinus (I).

RESULTS

Among fifteen preoperative embolizations for posterior fossa meningiomas performed between 2020 and 2024, we identified eight patients who agreed to our performing embolization of the MHT preoperatively（Online Supplemental Data）. MHT embolization was successfully achieved in all patients using the previously described method. The mean diameter of the MHT was 1.0 mm (range, 0.52mm-1.45 mm), and the mean branching angle of the MHT from the ICA was 118° (range, 50°-155°). Among the eight cases, the tentorial artery alone was the feeding vessel in five cases, and both the tentorial artery and the dorsal meningeal artery were feeding vessels in the remaining three cases. Complete obliteration was obtained in the first five cases（i.e. supplied with the tentrial artery alone)（supplementary figure 1）. None of the patients had cerebral infarction associated with distal embolization. One patient experienced a worsening of preoperatively observed abducens nerve palsy due to cranial nerve ischemia. Regarding the tumoral character, the mean maximum tumor diameter was 30.6 mm (range, 22 mm-49 mm), and the tumor attachment sites were the petroclival in six cases and CPA in two cases. Among them, the transpetrosal approach was selected in five cases, and the retrosigmoid approach in three cases. Gross total resection (GTR) was achieved in seven of eight cases. The mean estimated blood loss during surgical resection was 186 mL (range, 39–392 mL). The mean operative time was 431 min (range, 317-767 min).

DISCUSSION

The first-line embolic material for meningioma embolization is particulate; however, the use of *n*-BCA is increasing. In recent years, large case series of meningioma embolization using *n*-BCA have shown a low complication rate and a reduction in intraoperative blood loss.[8, 9] In addition, a comparative study between *n*-BCA and particles used for

intracranial tumor embolization showed no difference in complication rates.[10] Suzuki et al. conducted a retrospective evaluation for their twenty skull-base meningiomas treated with *n*-BCA, which showed high technical success without permanent complications.[11] The present study is the first report to focus on MHT embolization using *n*-BCA for posterior fossa meningiomas.

MHT embolization using particle

Several prior series of tumor embolization targeting the MHT and ILT have reported excellent outcomes: Robinson et al with five cases using PVA 150-250μm and no complications; Hirohata et al with seven cases using PVA 250-350μm and no complications; Waldron et al with 10 cases using PVA, coil, and microsphere and no complications; Raz et al 14 cases using 45-250μm PVA and no complications.[12-15] In the present series, we embolized the MHT using 12.5-33% *n*-BCA in eight cases, there was a single complication with worsening of an already present abducens nerve palsy. However, the advantage of the present technique is a higher success rate than the previous reports. The tumor embolization from the MHT and ILT might raise two concerns: a reflux of embolic material into the parent ICA which can lead to embolic infarcts within ICA territory; and a risk of cranial nerve ischemia due to embolic occlusion of vasa nervorum which is commonly supplied by these vessels.[14] Previous authors seem to be reluctant to use the *n*-BCA as an embolic material, which can lead to cranial nerve ischemia due to the high permeability. Another reason for the reluctance is that the feeding vessels of the skull base meningioma, including the MHT and ILT, potentially anastomose with the other meningeal arteries.[14] *n*-BCA can lead to a leak into the cerebral arteries, such as ICA and VA, via these meningeal arteries with a rich vascular network. Therefore, many authors recommend using particles, including PVA and microspheres, as the safest embolic material for the embolization of skull base meningiomas. Likewise, we consider large-sized particles (i.e. microspheres 300-500μm) as the safest material. A medial tentorial artery and a medial branch of the dorsal meningeal artery branching from MHT are known to have vasa nervorum, each feeding the oculomotor / trochlear nerve and abducens nerve.[16] The vasa nervorum consists of two functionally independent systems, an extrinsic and intrinsic vessels, which serve to supply the peripheral nerve to maintain its structural and functional requirements. The extrinsic vessels are located outside of the perineurium, and segmentally branch into radicular vessels, which supply the intrinsic vessels. The former is believed to have some collateral circulation, while the latter is not expected to have collateral circulation, and its vessel diameter is reported to be 100-200 μm.[17] Hence, caution should be exercised in the use of small particles less than 300 μm. Large particles are safe. However, their use requires more than 1.6F microcatheters. Raz et al. used a 1.6fr Headway Duo microcatheter (inner diameter is 0.0165 inch), which was the smallest diameter catheter in the series using particulate. The particle-compatible microcatheter limits the proper vessels which can be navigated, and it requires care to ensure that the catheter does not become wedged in position so that the particles can penetrate into the tumor in the bloodstream without reflux.[14] Such favorable conditions are likely to be limited: prior authors have reported low success rates (range, 32.1%-36%) when cannulating microcatheters into the MHT.[15, 18]

MHT embolization using NBCA and dual balloon protection

The advantage of MHT embolization with *n*-BCA was the high success rate of navigating the target vessel using smaller diameter microcatheters. We used 1.3F DeFrictor Nano catheters over the Chikai X10 micro guidewires, which were navigable even into narrow and tortuous vessels. The balloon catheters were useful in preventing the microguidewires and microcatheters from deviating into the distal ICA. As the balloon catheters could interfere with the microguidewires (i.e. Chikai X10) and sometimes made it difficult to navigate the microguidewires into the MHT, we advanced the balloon catheters to the cavernous portions from the petrous portions of the ICA after insertion of the tips of the microguidewires into the MHT. To prevent the distal migration of injected glue into the

ICA, we used dual balloon protection (i.e. balloon catheter and BGC). The reason for this is that glue can damage the balloon, which is inflated by the cavernous portion of the ICA. In these situations, the BGC acts as an airbag: In the unlikely event of balloon failure in the cavernous portion, the blockage of blood flow to the ICA by the BGC will prevent distal embolization of liquid embolic material to the ICA.

It is also useful to prevent glue attached to the tip of the microcatheter from migrating into the ICA when the microcatheter is removed. The drawbacks of this technique should also be discussed. The MHT has three branches (i.e. tentorial, inferior hypophyseal, and dorsal meningeal artery), most form a common trunk, however, their range is very short and they branch out soon. when the MHT as a feeding vessel has multiple branches (i.e. both the tentorial artery and the dorsal meningeal artery), it seems to lead to incomplete occlusion. In such cases, the microcatheter is usually inserted into one of the two branches: blood flow is maintained in the branch that is not inserted. On the other hand, to reduce complications, it is desirable to advance the microcatheter tip as far into the tumor as possible during tumor embolization using *n*-BCA. Therefore, a particle may be most effective as an embolic material if both a tentorial artery and a dorsal meningeal artery are developed as tumor feeders, and the MHT is thick enough to navigate a more than 1.6Fr microcatheter. Regarding *n*-BCA concentration, we currently believe that embolization with medium concentration (i.e. 25-33%) of *n*-BCA aimed at feeder occlusion is safer than low concentration of *n*-BCA. In our prior series of tumor embolization for the convexity meningiomas, we reported the efficacy of 10-12.5% *n*-BCA with high penetration and necrotic changes of the tumor.[19] The ultra-low concentration of *n*-BCA easily penetrates the tumor and even the dura mater at the site of tumor attachment, which connects with the normal meningeal artery at the tentorium and clivus. In our case, we used 12.5% *n*-BCA for petroclival meningioma with rich tumor vessel, the glue penetrated into the dural attachment of the tumor: the deeply penetrated glue could lead to cranial nerve ischemia (Figure 2). Therefore, caution seems to be needed as aggressive embolization using ultra-low concentration *n*-BCA for the skull base meningiomas can lead to cranial nerve ischemia due to embolic occlusion of vasa nervorum.

Limitation

This study was conducted at a single institution and the number of cases was small. Although our surgical outcomes were acceptable (i.e. relatively low blood loss, short operative time, and high rate of GTR), to demonstrate the true benefit of MHT embolization, comparisons with non-embolized cases and statistical studies using a matched cohort are needed. Furthermore, we observed only one recurrent case in this series. Preoperative embolization of meningiomas may decrease recurrence rates. However, the results for skull base meningiomas are completely unclear, and continued accumulation and tracking of cases is needed.

As mentioned above, embolic agents should be selected according to the form of MHT, and further experience with these selection criteria is needed. So far, if the MHT is thick enough to pass through a 1.6Fr or larger microcatheter, the conventional method using large particles is recommended as the first choice. Our method may be useful as an alternative when these large-diameter catheters are difficult to navigate. In addition, for extremely thin MHT/ILT cases that are difficult to treat even with our method, a distal balloon protection technique can be considered as salvage method. [14] We used the BGC to avoid distal migration of *n*-BCA, and have not experienced thromboembolic complications. However, a prior series of tumor embolization targeting the MHT and ILT had achieved same result without BGC. Further study (i.e. case-control study) will be needed to elucidate the usefulness of the BGC.

CONCLUSIONS

MHT embolization of posterior fossa meningiomas using *n*-BCA and a dual balloon catheter is a useful technique with a high procedural success rate. The microcatheter tip should be advanced as far into the tumor as possible, and dual balloon protection should be used to ensure prevention of reflux and migration of glue into the ICA. Using a medium to high concentration of *n*-BCA aimed at feeder occlusion may be useful in reducing the frequency of cranial nerve ischemia.

ACKNOWLEDGMENTS

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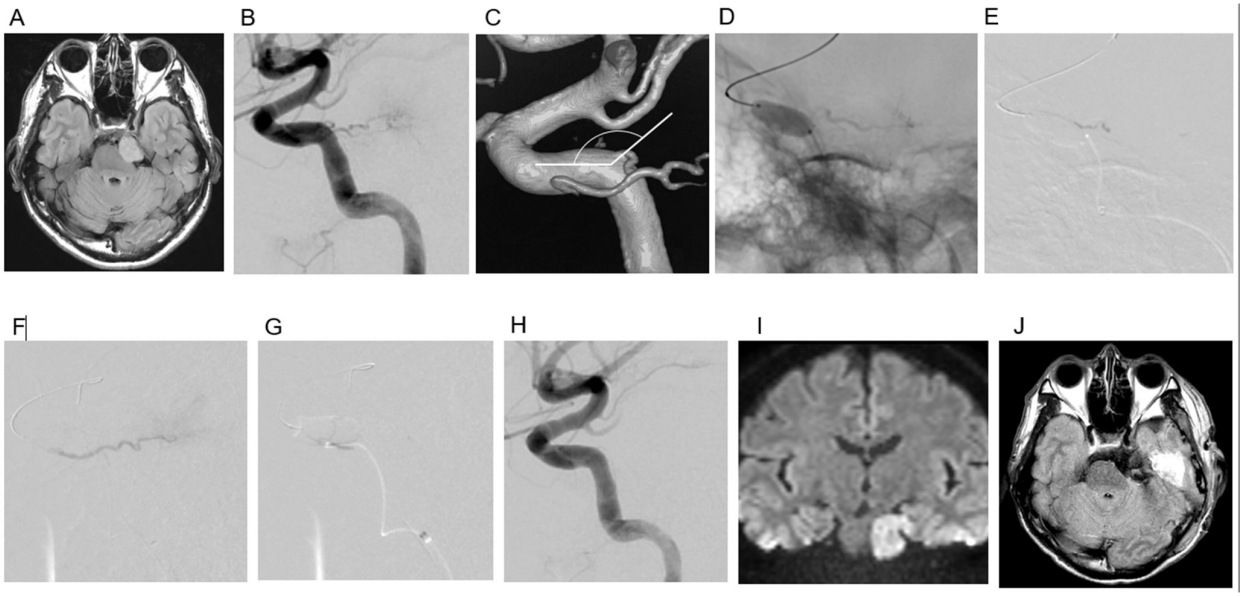
SUPPLEMENTAL FILES

Online Supplemental Data: Clinical feature of eight patients with the MHT embolization using by *n*-BCA

Case	Diameter of MHT (mm)	Branching angle	Obliteration of MHT	Concentration of *n*-BCA(%)	Infarction	CN impairment	Location	Approach	Maximum diameter(mm)	Blood loss(ml)	Surgical time(min)	Simpson grade	GTR

1	1.45	110°	Partial	12.5	No	No	Petro-clival	Trans-petrosal	49	85	650	II	Yes
2	1.03	155°	Partial	12.5	No	No	CPA	Retro-sigmoid	29	100	317	II	Yes
3	0.89	150°	Complete	12.5	No	No	Petro-clival	Retro-sigmoid	39	50	336	II	Yes
4	1.07	108°	Complete	12.5	No	No	CPA	Retro-sigmoid	24	39	326	II	Yes
5	0.52	128°	Partial	12.5	No	Yes	Petro-clival	Trans-petrosal	30	350	458	IV	No
6	1.25	90°	Complete	33	No	No	Petro-clival	Trans-petrosal	27	222	767	II	Yes
7	0.87	150°	Complete	33	No	No	Petro-clival	Trans-petrosal	25	392	325	II	Yes
8	0.92	50°	Complete	25	No	No	Petro-clival	Trans-petrosal	22	250	272	II	Yes



Supplementary FIG 1 . Adult patient with petroclival meningioma (A). Left internal carotid angiogram (lateral view) showed supply to the tumor from the enlarged MHT and ILT(B). In 3D-angiogram, A Branching angle of the MHT from the ICA was 150°, and the diameter of the MHT was 0.87mm(C). Super selective angiogram via a DeFrictor showed that the tip of the microcatheter positioned in the MHT(D), and the ILT(F) . Immediately after glue injection and removal of the microcatheter from the MHT(E) and the ILT(G). Postprocedural angiogram showed a complete obliteration of the feeding vessels(H). Postprocedural diffusion weighted image showed an intra-tumoral ischemia and no evidence of cerebral infarction(I). Postoperative FLAIR image showed a total removal of the tumor(J).

STROBE Statement—Checklist of items that should be included in reports of ***cohort studies***

	Item No	Recommendation	Page No
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1
		(*b*) Provide in the abstract an informative and balanced summary of	1

		what was done and what was found	
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	2
Objectives	3	State specific objectives, including any prespecified hypotheses	2
Methods			
Study design	4	Present key elements of study design early in the paper	2
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	2
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up	2
		(*b*) For matched studies, give matching criteria and number of exposed and unexposed	ND
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	2
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	ND
Bias	9	Describe any efforts to address potential sources of bias	ND
Study size	10	Explain how the study size was arrived at	ND
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	ND
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	ND
		(*b*) Describe any methods used to examine subgroups and interactions	ND
		(*c*) Explain how missing data were addressed	ND
		(*d*) If applicable, explain how loss to follow-up was addressed	ND
		(*e*) Describe any sensitivity analyses	ND
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	ND
		(b) Give reasons for non-participation at each stage	ND
		(c) Consider use of a flow diagram	ND
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	ND
		(b) Indicate number of participants with missing data for each variable of interest	ND
		(c) Summarise follow-up time (eg, average and total amount)	ND
Outcome data	15*	Report numbers of outcome events or summary measures over time	ND

Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	ND
		(*b*) Report category boundaries when continuous variables were categorized	ND
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	ND
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	ND
Discussion			
Key results	18	Summarise key results with reference to study objectives	5
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	7
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	7
Generalisability	21	Discuss the generalisability (external validity) of the study results	6
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	1

*Give information separately for exposed and unexposed groups.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at http://www.strobe-statement.org.