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ABSTRACT

BACKGROUND AND PURPOSE: Skull base tumors are commonly supplied by dural branches of the meningohypophyseal and inferolateral trunks. Embolization through these arteries is often avoided due to technical challenges and inherent risks; however, successful embolization can be a valuable surgical adjunct. We aimed to review the success and complications in our series of tumor embolizations through the meningohypophyseal and inferolateral trunks.

MATERIALS AND METHODS: We performed a retrospective review of patients with tumor treated with preoperative embolization at our institution between 2010 and 2020. We reviewed the following data: patients' demographics, tumor characteristics, endovascular embolization variables, and surgical results including estimated blood loss, the need for transfusion, and operative time.

RESULTS: Among 155 tumor embolization cases, we identified 14 patients in whom tumor embolization was performed using the meningohypophyseal ($n = 13$) or inferolateral ($n = 4$) trunk. In this group of patients, on average, 79% of tumors were embolized. No mortality or morbidity from the embolization procedure was observed in this subgroup of patients. The average estimated blood loss in the operation was 395 mL (range, 200–750 mL). None of the patients required a transfusion, and the average operative time was 7.3 hours.

CONCLUSIONS: Some skull base tumors necessitate embolization through ICA branches such as the meningohypophyseal and inferolateral trunks. Our series demonstrates that an effective and safe embolization may be performed through these routes.

ABBREVIATION: PVA = polyvinyl alcohol

Preoperative embolization of extra-axial brain tumors is often performed to devascularize a tumor and facilitate a safe surgical resection.[1-6] Such embolization has been associated with improved outcomes, including reduced surgical blood loss,[7-11] shorter operative times,[9] more complete resections,[3] increased progression-free survival,[12] and decreased surgical complications.[13] Preoperative embolization for skull base tumors, however, remains controversial, particularly for tumors supplied by the meningohypophyseal and inferolateral trunks. Embolization through these ICA branches poses several challenges. The meningohypophyseal and inferolateral trunks can be small and, therefore, difficult to catheterize. They supply the vasa nervorum of cranial nerves, placing those nerves at risk of ischemia during embolization. Finally, the short course of these branches risks reflux of embolic material into the ICA itself. Thus, tumor embolization through the meningohypophyseal and inferolateral trunks has been considered a "precarious undertaking."[13]

Despite these concerns, there is mounting evidence that preoperative embolization of skull base tumors through the meningohypophyseal and inferolateral trunks can be both safe and effective if done properly.[14-16]

In this study, we aimed to review our series of skull base tumors treated with preoperative embolization through the meningohypophyseal and/or inferolateral trunk to better characterize the safety and efficacy of embolization in this subgroup.

MATERIALS AND METHODS

Study Design

This study was approved by NYU institutional review board and conducted in accordance with the Health Portability and Accountability Act. We performed a retrospective review of all

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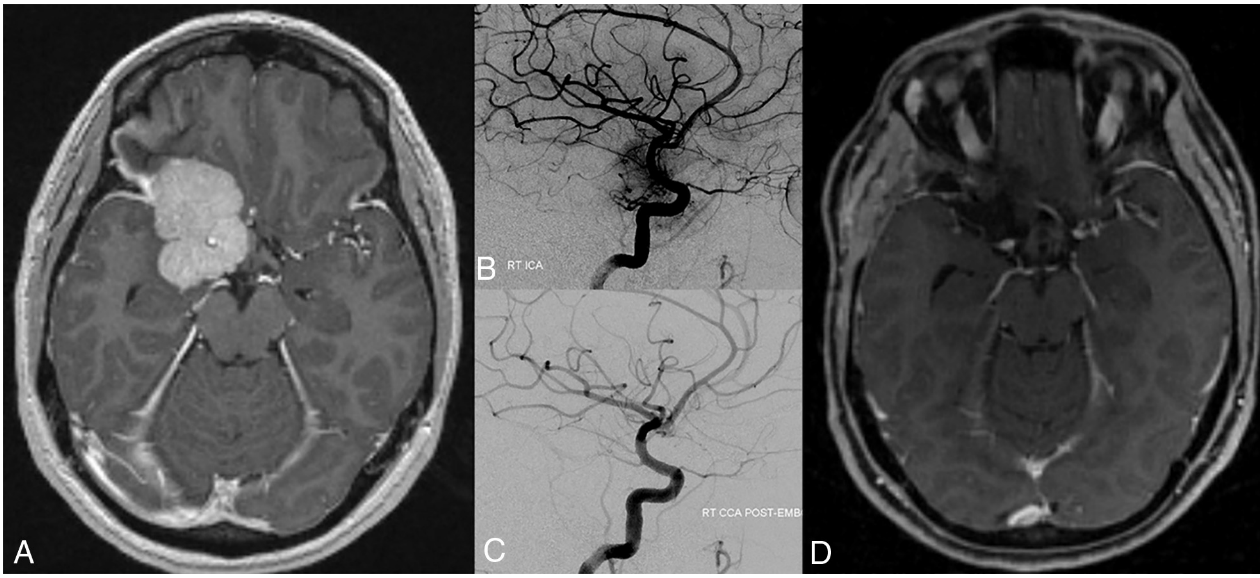

FIG 1. A patient with a large right sphenoid wing meningioma with encasement of the ICA visible on a T1-weighted, axial, postcontrast image (*A*). Right ICA DSA injection in a lateral view (*B*) demonstrates the supply to the tumor from an enlarged meningohypophyseal trunk. After selective embolization through both the meningohypophyseal trunk and indirectly from the middle meningeal artery, a final right common carotid artery injection in a lateral view (*C*) demonstrates interval 90% tumor embolization. Complete gross resection of the meningioma is visible on the T1-weighted, axial, postcontrast image (*D*). RT indicates right; CCA, common carotid artery; EMB, embolization.

patients who underwent preoperative brain tumor embolization from 2010 to 2020. Patient and tumor data were collected, including patient age and sex, tumor size and location, and the final pathologic diagnosis. In addition, details of the embolization procedure were collected, including the vessels embolized, percentage of tumor devascularization, and any intra- or postprocedural complications. Finally, surgical variables were collected, including estimated blood loss, the need for transfusion, and operative time. Two neurointerventionalists (E.R., and M.S.) independently evaluated the angiographic images before and after embolization to evaluate the percentage of tumor embolization and arrived at a final value by consensus.

Embolization Procedure

The decision to perform preoperative embolization and its goals were discussed in a multidisciplinary fashion among the treating neurosurgeons and neurointerventionalists. Patients were typically scheduled for embolization 1 to 2 days before the planned surgical resection. All embolization procedures were performed with the patient under general anesthesia, and intravenous steroids were administered at the start of each procedure. The procedure was performed using a sheathless 5F catheter to minimize the size of the arteriotomy. A comprehensive angiographic evaluation was first performed to completely characterize the supply to each artery. Once the target arteries for embolization were identified, there was an additional discussion in the control room with the neurosurgeon to reassess the goals and safety. For embolization, either an Excelsior SL-10 (Stryker) or a Headway Duo (MicroVention) microcatheter was navigated over a Synchro-14 or -10 soft microwire (Stryker). After appropriate superselective microangiography to verify the catheter position and the collateral anastomoses, embolization was performed using Contour Polyvinyl Alcohol (PVA) particles (Boston Scientific) diluted in 100% contrast. Embolization began with 45- to 150-μm PVA particles until remarkable stagnation was noted in the tumor bed. Subsequent embolization was then performed with 150- to 250-μm PVA particles, which were sometimes followed with deployment of detachable coils in the main trunk. At the end of the embolization, a full angiographic evaluation was obtained to demonstrate the possible presence of collateral flow and an accurate estimation of devascularization. The patient was then extubated and kept in the neurointensive care unit overnight for neurologic observation.

RESULTS

Among 155 tumor embolization cases performed from 2010 and 2020, we identified 14 patients in whom embolization was performed through the meningohypophyseal ($n = 13$) or inferolateral ($n = 4$) trunk. Three patients had embolization through both trunks (Online Supplemental Data).

In the included patients, on average, 79% (range, 50%–95%) of the tumor was embolized. No morbidity or mortality postembolization was observed in this subgroup of patients. The mean estimated blood loss during surgical resection was 395 mL (range, 200–750 mL). None of the patients required a transfusion, and the average operative time was 7.3 hours.

Case Examples

In a patient with a large, right sphenoid wing meningioma with encasement of the ICA (Fig 1), a right ICA injection demonstrated the supply to the tumor from an enlarged meningohypophyseal trunk. After selective embolization through the meningohypophyseal trunks and indirectly from the middle meningeal artery, the final right common carotid artery injection demonstrated interval 90% tumor embolization. The patient woke up from the procedure

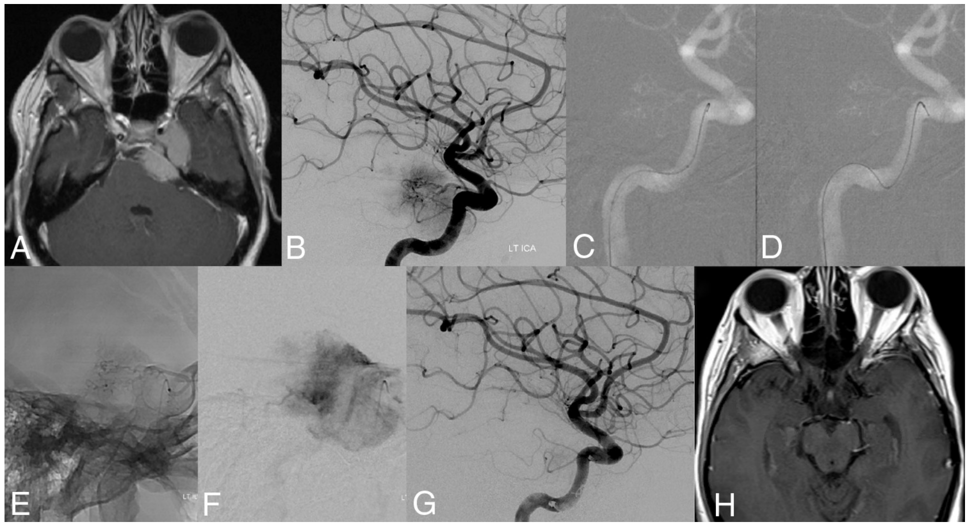

FIG 2. A patient with a Meckel cave meningioma also with involvement of the cavernous sinus visible on a T1-weighted, axial, postcontrast image (*A*). Right ICA DSA injection in lateral view (*B*) demonstrates the supply to the tumor from an enlarged inferolateral trunk from the left ICA. Inferolateral trunk catheterization is performed with a Headway Duo over a Synchro-14 microguidewire (*C* and *D*). MICRO DSA performed through a microcatheter on a lateral view (unsubtracted, *E*, and subtracted, *F*) better demonstrates the selective supply to the meningioma. Final lateral view ICA injection (*G*) demonstrates marked interval reduction of blush in the region of the tumor. Complete gross resection of the meningioma is visible on a T1-weighted, axial, postcontrast image (*H*). LT indicates left.

at baseline and underwent an operation the following day with estimated blood loss of 200 mL without the need for a transfusion with complete gross resection of the meningioma.

In a patient with a Meckel cave meningioma with involvement of the cavernous sinus, an angiogram showed most of the supply arising from the inferolateral trunk from the left ICA, (Fig 2) and the inferolateral trunk arising from the lateral inferior aspect of the horizontal cavernous ICA. Catheterization was performed with a Headway Duo over a Synchro-14 microguidewire. MICRO DSA performed through a microcatheter better demonstrated the selective supply to the meningioma. It is important to have runoff in the vessel and not aim for a wedged position if embolization with particles is planned. At the end of the embolization, coils are placed at the proximal inferolateral trunk with the final angiography demonstrating marked interval reduction of blush in the region of the tumor. The patient woke up from the procedure at baseline and underwent an operation the following day with an estimated blood loss of 250 mL without the need for a transfusion, with complete gross resection of the meningioma.

Additional cases are illustrated in detail in Figs 3 and 4 and the Online Supplemental Data.

DISCUSSION

Preoperative tumor embolization is typically performed to facilitate surgical resection. Significant devascularization not only reduces surgical blood loss but also induces necrosis within the tumor, which makes the tumor more amenable to aspiration. Meningiomas and other extra-axial brain tumors that arise from the dura receive most of their blood supply from the dural feeders. Surgical control of the dural supply is straightforward for a convexity meningioma, in which the dural base is encountered and circumferentially disconnected before tumor resection. The dural base of skull base tumors, however, is typically deep within the surgical view; therefore, tumor resection must be performed before the dural arterial supply can be surgically controlled. In these cases, preoperative embolization can provide that dural arterial control. Skull base tumors such as medial sphenoid wing and clival or clinoidal meningiomas often receive dural supply from the meningohypophyseal and/or inferolateral trunk and may benefit most from embolization.[9] We present a series of 14 patients with skull base tumors who underwent preoperative embolization through the meningohypophyseal and/or inferolateral trunks. We demonstrate that this procedure can be both safe and highly effective in terms of tumor devascularization. To our knowledge, this is the largest such series published to date.

The meningohypophyseal trunk is classically described as arising from the posterior vertical cavernous segment of the ICA and, as the name indicates, it gives off supply to the pituitary gland and the meninges. The inferolateral trunk instead is usually a pure meningeal vessel, arising from the lateral horizontal cavernous ICA. The supply to the meninges of the medial middle cranial fossa has been described in detail elsewhere.[17-19] Briefly, feeders may come off the meningohypophyseal trunk, inferolateral trunk, and middle meningeal artery and the accessory meningeal, recurrent ophthalmic, and ascending pharyngeal arteries. The amount of territory supplied by each of these branches is extremely variable from human to human, confirming the extreme importance of thorough angiographic detailed evaluation before performing skull base tumor embolization.

Several prior series of tumor embolization through the meningohypophyseal and/or inferolateral trunk have also reported excellent outcomes: Robinson et al[14] with 5 patients and no complications; Hirohata et al[15] with 7 patients and no complications; and Waldron et al[16] with 10 patients and no complications.

The reluctance of performing embolization through the meningohypophyseal and inferolateral trunks arises from 2 concerns: First, there is a risk of reflux of embolic material into the parent

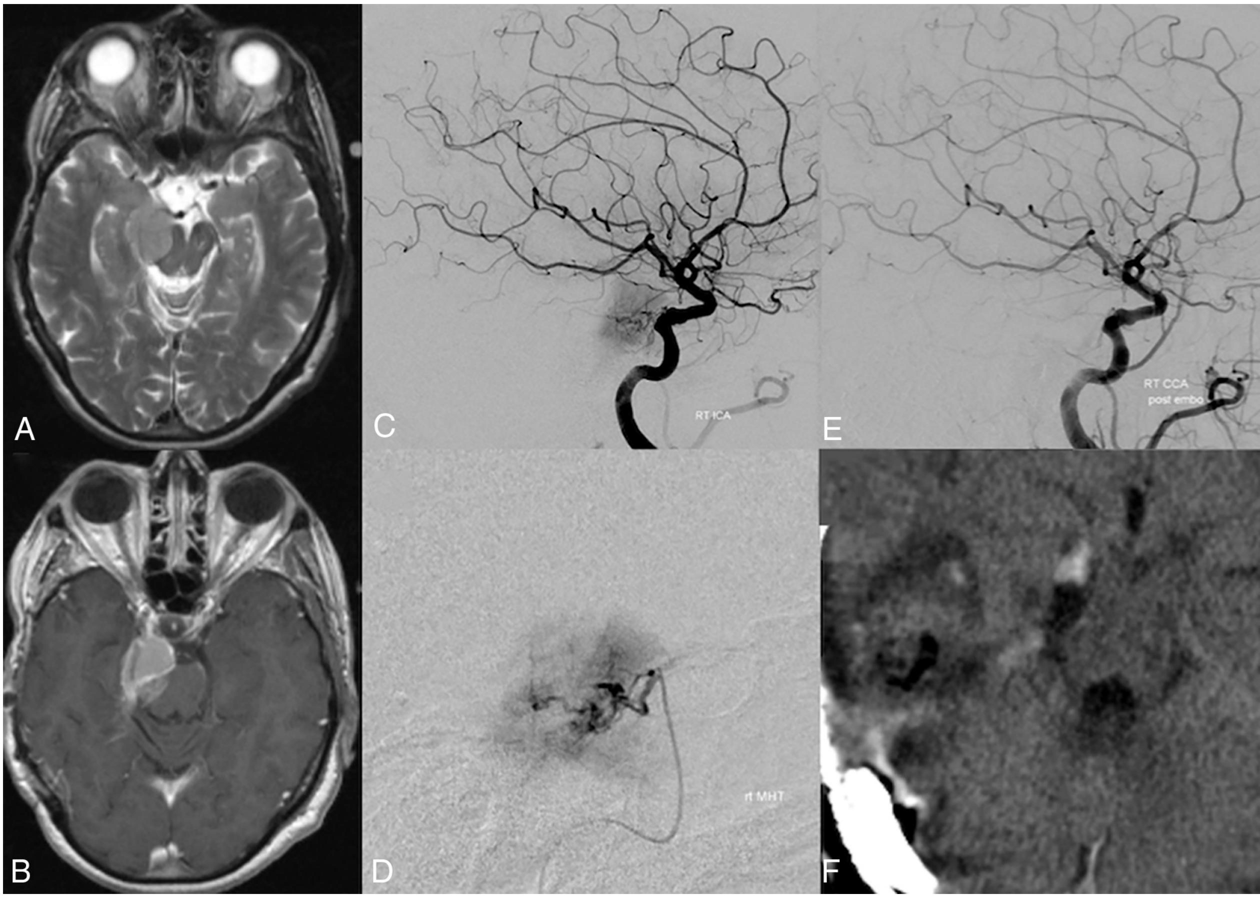

FIG 3. A patient with a right petroclival meningioma as shown on MR imaging T2 (*A*) and postcontrast T1 (*B*). A right ICA injection lateral view DSA (*C*) demonstrates a large blush supplied by the meningohypophyseal trunk. Selective catheterization and DSA (*D*) with a Marathon microcatheter (Medtronic), followed by embolization with 45- to 150- and 150- to 250-μm particles. Final right ICA injection, lateral view DSA (*E*) demonstrates resolution of the previously seen blush. Final CT (*F*) postsurgical resection demonstrates complete excision with a small amount of retraction injury in the right temporal lobe.

ICA, which can lead to embolic infarcts within the ICA territory. Second, there is a risk of causing ischemia to the cranial nerves commonly supplied by these vessels.[13] On the basis of this experience and others, however, it seems that reluctance to embolize through the meningohypophyseal and inferolateral trunks is dogmatic and unjustified, and safe embolization can be achieved if the following principles are followed.

Thorough Anatomic Evaluation

The main risk of tumor embolization is inadvertent embolization into the cerebral circulation. The dural arteries that supply most skull base tumors form a rich anastomotic network, creating potential, dangerous collaterals to the ICA, ophthalmic artery, and vertebrobasilar circulation. It is, therefore, important to perform a thorough investigation of the arterial supply to a tumor, which typically includes injections of the bilateral ICAs, external carotid arteries, and at least 1 vertebral artery. Most important, skull base tumors may also receive significant pial supply that should be well-characterized. It is also important after the embolization to evaluate possible residuals related to reorganization of the tumor vascular supply induced by embolization and to properly assess the extent of the embolization achieved.[4,6,20-22]

Catheter Positioning

Catheterization of the meningohypophyseal trunk is typically easier than of the inferolateral trunk. The meningohypophyseal trunk arises from the posterior genu of the cavernous ICA and courses posteriorly. Conversely, the inferolateral trunk arises from the lateral aspect of the horizontal segment of the cavernous ICA and curves posteriorly, forming a double curve. With the use of particles, we believe it is safest to obtain a nonwedged position with the catheter. While wedging provides flow arrest that can promote penetration of liquid embolics, a nonwedged position allows persistent flow through the target vessel. This can help carry particles distally as close as possible to the capillary bed.

Choice of Embolic Material

Several different options exist for embolic materials in tumor embolization. Particles include PVA (Contour) microspheres (Embosphere Microspheres; Merit Medical) and absorbable gelatin powder (Gelfoam; Pfizer). Liquid embolics include *n*-butyl cyanoacrylate (Trufill; Cerenovus) and ethylene-vinyl alcohol copolymer (Onyx; Medtronic). Finally, coils can also be used for proximal embolization. In our experience, particles provide the safest and most effective means of tumor embolization for skull

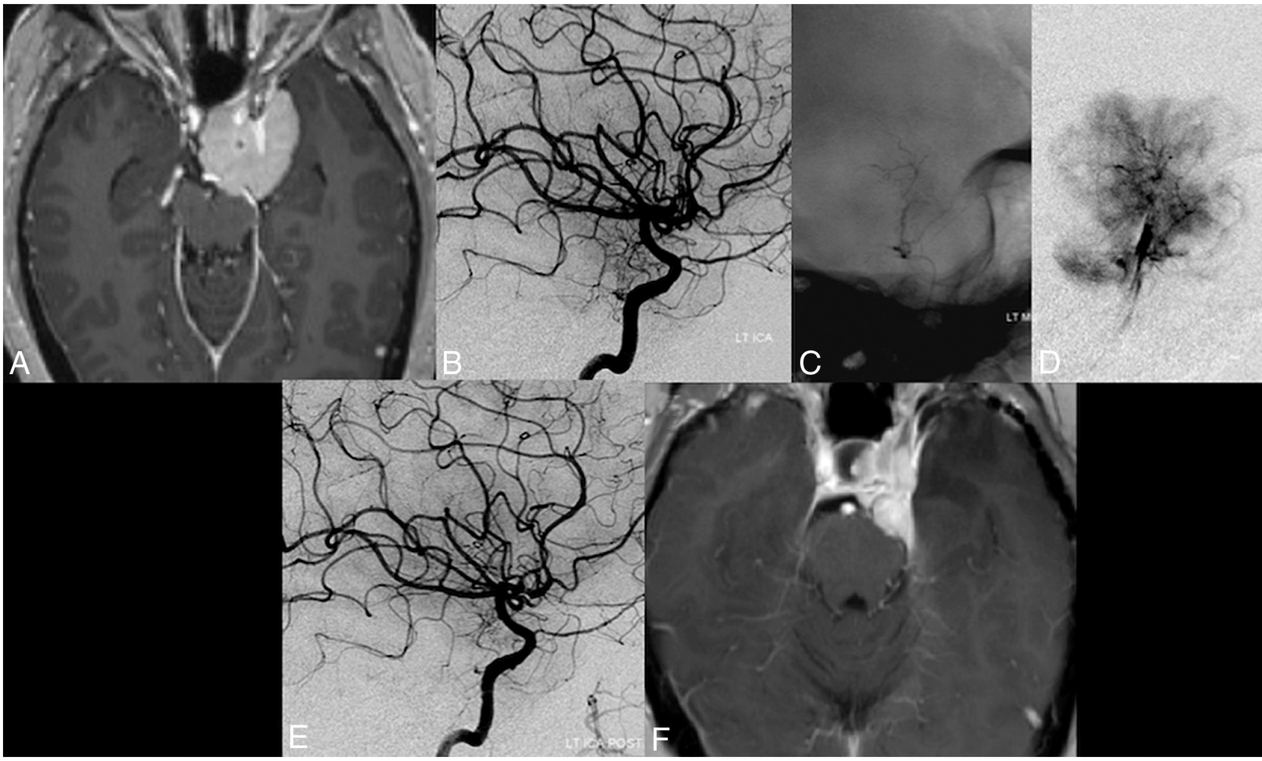

FIG 4. A patient with a left anterior clinoid meningioma as shown on postcontrast T1 MR imaging (*A*). A left ICA injection, lateral view DSA (*B*), demonstrates a large blush supplied by the meningohypophyseal trunk. Selective catheterization with unsubtracted (*C*) and subtracted (*D*) views with a Marathon microcatheter, followed by embolization with 45- to 150-μm particles. A final left ICA injection, lateral view DSA (*E*) demonstrates 60% embolization of the tumor. A final MR imaging T1 postcontrast (*F*) postsurgical resection demonstrates partial excision of the mass.

base tumors. Small particles (ie, PVA, 45–150 µm; Embosphere Microspheres, 40–120 μm) can penetrate the vascular bed of a tumor up to the distal arterioles. Progressively larger particles then fill the more proximal arterioles. By this method, the tumor is devascularized from the distal bed outward. While liquid embolics can similarly penetrate deep into a tumor, they can also permeate the vasa nervorum of cranial nerves and can more quickly reflux into unwanted territories.

As Low as Reasonably Achievable Principles

Embolization of large skull base tumors can be a time-consuming process with long fluoroscopy times. This can, therefore, risk radiation injury such as hair loss or skin burns. It is, therefore, important to follow as low as reasonably achievable principles. Collimation, reduced roadmap fluoroscopic rates (ie, 4 pulses per second), use of only a single plane at a time, and frequent changes of the fluoroscopic angles can help minimize the risk of radiation injury.[21]

Embolization

Paramount to safe embolization is preventing reflux into the ICA or any other potentially dangerous collaterals. The operator should define acceptable limits for reflux. This can be aided by reference images demonstrating the relevant anatomy or marking limits on the roadmap screen with a washable marker. We recommend significantly diluting particles to prevent clumping, which can inadvertently occlude the arterioles before effective tumor devascularization.[21,22] Repeat dilution is often required to maintain sufficient dilution. The injections should be brief, gentle, and pulsatile, giving time between injections for the particles to flow distally.

Postembolization Anatomic Evaluation

Embolization can lead to reorganization of the tumor vascular supply. We, therefore, recommend thoroughly evaluating the relevant feeders after embolization for additional embolic targets and to properly assess the extent of embolization.

Balancing Risks of Embolization versus Surgical Resection

Surgery and embolization must be coordinated toward a shared goal. The ultimate purpose is not just to control blood flow but to minimize the overall morbidity and maximize the efficiency of surgical resection. A conservative or inefficient embolization is a low risk–but-unhelpful procedure. Conversely, a thoroughly aggressive embolization may be more hazardous but ultimately more helpful to the surgeon. The embolization and resection should be viewed by the patient and treating physicians as a single combined treatment with shared risks and benefits. Also, a tumor that benefits the most from embolization is one in which the supplying vessels come from its deep part away from the surgical view, in the "dark side" of the tumor; thus, a convexity meningioma is the least challenging with respect to devascularizing its blood supply because the dural blood supply is encountered as soon as the cranial flap is elevated and the dura overlying the tumor is exposed; medially located skull base tumors instead, such as tuberculum sellae, medial sphenoid wing, or clinoid meningioma, often supplied by ICA branches of the meningohypophyseal and inferolateral trunks, are ones that may benefit the most from embolization,[9] unless they have significant pial blood supply as well.

We did not encounter complications such as neuropathy or intratumoral hemorrhage in our series; however, the association between the use of a small amount of PVA and hemorrhage has been previously reported.[23] We agree with other authors[24] who believe that the finalization of the tumor embolization with larger particles and possibly with coils, as was routinely done in the current series, may mitigate this risk.

We acknowledge several limitations to this study. First, it is retrospective in nature, which limits the available treatment and outcome details. Second, it is difficult to identify a metric that directly proves the utility of preoperative embolization. On an institutional basis, the best measure of utility is often the surgeon's subjective opinion of the tumor resection after embolization. Blood loss can be a good surrogate for effective tumor devascularization, though estimated blood loss during an operation is a notoriously inaccurate measure.

CONCLUSIONS

Preoperative embolization of skull base tumors through the meningohypophyseal and inferolateral trunks can be performed safely and with high efficacy if certain procedural principles are followed.

Disclosure forms provided by the authors are available with the full text and PDF of this article at www.ajnr.org.

REFERENCES

1. Manelfe C, Guiraud B, David J, et al. **Embolization by catheterization of intracranial meningiomas [in French].** *Rev Neurol (Paris)* 1973;128:339–51 Medline
2. Richter HP, Schachenmayr W. **Preoperative embolization of intracranial meningiomas.** *Neurosurgery* 1983;13:261–68 CrossRef Medline
3. Teasdale E, Patterson J, McLellan D, et al. **Subselective preoperative embolization for meningiomas: a radiological and pathological assessment.** *J Neurosurg* 1984;60:506–11 CrossRef Medline
4. Manelfe C, Lasjaunias P, Ruscalleda J. **Preoperative embolization of intracranial meningiomas.** *AJNR Am J Neuroradiol* 1986;7:963–72 Medline
5. Dean BL, Flom RA, Wallace RC, et al. **Efficacy of endovascular treatment of meningiomas: evaluation with matched samples.** *AJNR Am J Neuroradiol* 1994;15:1675–80 Medline
6. Nelson PK, Setton A, Choi IS, et al. **Current status of interventional neuroradiology in the management of meningiomas.** *Neurosurg Clin N Am* 1994;5:235–59 CrossRef Medline
7. Manaka H, Sakata K, Tatezuki J, et al. **Safety and efficacy of preoperative embolization in patients with meningioma.** *J Neurol Surg B Skull Base* 2018;79:S328–33 CrossRef Medline
8. Gruber A, Killer M, Mazal P, et al. **Preoperative embolization of intracranial meningiomas: a 17-years single center experience.** *Minim Invasive Neurosurg* 2000;43:18–29 CrossRef Medline
9. Chen L, Li DH, Lu YH, et al. **Preoperative embolization versus direct surgery of meningiomas: a meta-analysis.** *World Neurosurg* 2019;128:62–68 CrossRef Medline
10. Raper DM, Starke RM, Henderson F Jr, et al. **Preoperative embolization of intracranial meningiomas: efficacy, technical considerations, and complications.** *AJNR Am J Neuroradiol* 2014;35:1798–804 CrossRef Medline
11. Suzuki K, Nagaishi M, Matsumoto Y, et al. **Preoperative embolization for skull base meningiomas.** *J Neurol Surg B Skull Base* 2017;78:308–14 CrossRef Medline
12. Macpherson P. **The value of pre-operative embolisation of meningioma estimated subjectively and objectively.** *Neuroradiology* 1991;33:334–37 CrossRef Medline
13. Ilyas A, Przybylowski C, Chen CJ, et al. **Preoperative embolization of skull base meningiomas: a systematic review.** *J Clin Neurosci* 2019;59:259–64 CrossRef Medline
14. Robinson DH, Song JK, Eskridge JM. **Embolization of meningohypophyseal and inferolateral branches of the cavernous internal carotid artery.** *AJNR Am J Neuroradiol* 1999;20:1061–67 Medline
15. Hirohata M, Abe T, Morimitsu H, et al. **Preoperative selective internal carotid artery dural branch embolisation for petroclival meningiomas.** *Neuroradiology* 2003;45:656–60 CrossRef Medline
16. Waldron JS, Sughrue ME, Hetts SW, et al. **Embolization of skull base meningiomas and feeding vessels arising from the internal carotid circulation.** *Neurosurgery* 2011;68:162–66; discussion 69 CrossRef Medline
17. Geibprasert S, Pongpech S, Armstrong D, et al. **Dangerous extracranial-intracranial anastomoses and supply to the cranial nerves: vessels the neurointerventionalist needs to know.** *AJNR Am J Neuroradiol* 2009;30:1459–68 CrossRef Medline
18. Shapiro M. **Middle Meningeal Artery.** *Neuroangio.org* 2022. http://neuroangio.org/anatomy-and-variants/middle-meningeal-artery. Accessed July 12, 2022
19. Shapiro M. **Ascending Pharyngeal Artery.** *Neuroangio.org* 2022; http://neuroangio.org/anatomy-and-variants/ascending-pharyngeal-artery/2020. Accessed July 12, 2022
20. Jo KI, Kim B, Cha MJ, et al. **Safety and efficacy of medium-sized particle embolisation for skull-base meningioma.** *Clin Radiol* 2016;71:335–40 CrossRef Medline
21. Thierry-Chef I, Simon SL, Miller DL. **Radiation dose and cancer risk among pediatric patients undergoing interventional neuroradiology procedures.** *Pediatr Radiol* 2006;36(Suppl 2):159–62 CrossRef Medline
22. Wakhloo AK, Juengling FD, Van Velthoven V, et al. **Extended preoperative polyvinyl alcohol microembolization of intracranial meningiomas: assessment of two embolization techniques.** *AJNR Am J Neuroradiol* 1993;14:571–82 Medline
23. Carli DF, Sluzewski M, Beute GN, et al. **Complications of particle embolization of meningiomas: frequency, risk factors, and outcome.** *AJNR Am J Neuroradiol* 2010;31:152–54 CrossRef Medline
24. Kallmes DF, Evans AJ, Kaptain GJ, et al. **Hemorrhagic complications in embolization of a meningioma: case report and review of the literature.** *Neuroradiolog* 1997;39:877–80 CrossRef Medline