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The role of interventional neuroradiology in the management of skull base tumours and related surgical complications

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Abstract. *The role of interventional neuroradiology in the management of skull base tumours and related surgical complications.* The management of hypervascular skull base tumours is complex and requires a multidisciplinary approach. Skull base surgery may be challenging because of the risk of serious intra-operative bleeding and of potential injuries to lower cranial nerves and/or large cervical vessels. Over the last four decades, advances in neuro-interventional procedures have produced a range of adjunctive endovascular techniques in addition to conventional surgery. Digital subtraction angiography (DSA) allows for a better understanding of tumour vascularisation and its relationship with surrounding vessels.[1-3] Tumoural devascularisation and the occlusion of feeding arteries is a useful adjunct to surgery because it allows for the reduction of intra-operative blood loss and induces ischaemic necrosis of the tumour. Finally, surgery-related iatrogenic vascular lesions may be successfully treated with endovascular techniques.[4] Nevertheless, endovascular procedures in the head and neck region are associated with infrequent but potentially serious complications.[5,6] An extensive and comprehensive knowledge of head and neck vascular anatomy is therefore necessary. This article provides a review of the indications for, and results of, diagnostic, pre-operative and therapeutic endovascular procedures for the management of skull base tumours and related surgical complications.

Indications

DSA

The development of non-invasive imaging techniques such as Magnetic Resonance Imaging (MRI) and Computed Tomography (CT) has reduced the indications of DSA for the pre-surgical evaluation of head and neck tumours. However, DSA remains the best imaging method for the evaluation of tumoural vascular components. When non-invasive imaging suggests that surgical access is difficult because of tumoural hypervascularisation and proximity to large vessels, DSA is often performed to facilitate the elaboration of the surgical strategy.[1-3] Indeed, surgical planning and the indication of pre-operative embolisation depend on the tumoural arterial feeders and venous drainage, the haemodynamic pattern (e.g. arterio-venous shunts), the presence of dangerous anastomoses with intracranial circulation and the proximity of important vessels (e.g. internal carotid (ICA) or vertebral arteries (VA)).[7,8] However, the availability and safety of DSA is clearly related to the hospital interventional neuroradiology workflow. In large hospitals with a high number of patients, many DSA and embolisations are performed in daily practice, leading to very low complication rates.

Presurgical embolisation

The usefulness of the pre-operative embolisation of skull base tumours continues to be controversial in only a few respects.[9,10] This procedure is routinely performed by most teams and recognised as a useful adjunct to surgery.[3,5] Its main objective is to reduce tumoural vascularisation in order to minimise intra-operative blood loss and induce ischaemic necrosis of the tumour. Reduced bleeding makes surgical resection safer and allows for better intra-operative visualisation. Ischaemic necrosis may cause softening of the tumour and facilitate resection. Complete resection is made easier, with shorter surgical times, higher rates of complete resection and lower risk of recurrence.[6] Although most hypervascular skull base tumours may benefit from presurgical embolization,[6] the literature mainly focuses on meningiomas,[1,11-13] paragangliomas,[7,14-16] juvenile angiofibromas[17] and haemangiopericytomas.[18] In the pre-operative assessment of large tumours involving the ICA or vascularised by its branches, a temporary balloon test occlusion

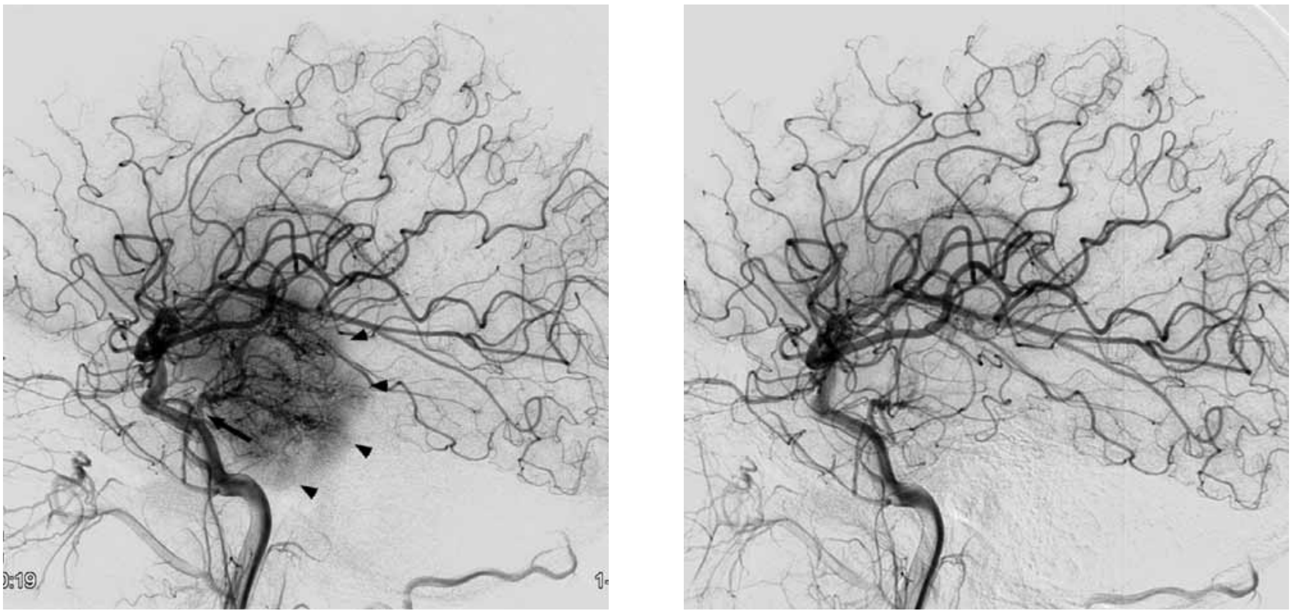

Figure 1
Pre-operative embolisation of a petroclival meningioma in a 29-year-old man.
Lateral view of a common carotid artery shows a tumoural blush (arrowheads) fed by the meningohypohyseal trunk (arrow).
The same view after embolisation with calibrated microspheres shows the complete devascularisation of the meningioma.

may be performed to assess the safety of permanent balloon occlusion prior to resection or of intra-operative ICA ligature.[19]

Palliative embolisation

Complete surgical tumoural resection is the only curative treatment for skull base tumours. However, when the expected surgery-related morbidity exceeds the clinical benefit, tumoural embolisation represents an alternative palliative procedure that may relieve symptoms temporarily or definitively. In the case of massive bleeding from a skull base tumour, surgical control of the bleeding may be difficult. Endovascular embolisation techniques are safe and efficient ways of controlling unstoppable bleeding in these patients.[20]

Management of surgery-related complications

Iatrogenic vascular injuries during skull base surgery mostly occur in transsphenoidal procedures and they represent potentially life-threatening conditions. Surgery-induced carotid pseudoaneurysms may cause thromboembolism and may rupture, causing subarachnoid haemorrhage, massive nasal or oral bleeding or a carotid-cavernous fistula.[4] Their management has benefited from the latest advances in the endovascular treatment of intracranial aneurysms.

Technical aspects

Diagnostic procedures are most often performed under local anaesthesia whereas interventional procedures should be performed under general anaesthesia because complete immobilisation is required and embolisation in the external carotid artery (ECA) territory may be quite painful. The most effective tumoural devascularisation is obtained by occluding the distal tumoural vascular bed, not only the arterial feeders. To achieve this objective, several embolic agents are available. Particulate embolic agents (polyvinyl-alcohol (PVA)), gelatine sponge powder and microspheres allow for the efficient occlusion of the tumoural vascular bed (Figure 1) but their use also needs more expertise. Indeed, they are not radiopaque and there is a risk of non-target embolisation resulting from either reflux or the opening of collaterals. The size of occluded vessels is related to the size of particles[21] and particles ranging from 100 mm to

300 mm and from 300 mm to 500 mm in size are more likely to occlude the tumoural vascular bed.[22] Particles smaller than 50 mm could pass through tumoural arteriovenous shunts[23] and reach the systemic circulation in case of patent foramen ovale, whereas larger particles would occlude arterial feeders without reaching the tumoural vascular bed. For this reason and although they are more expensive than PVA or gelatine sponge particles, calibrated microspheres are preferred by most teams because they achieve safer and more efficient devascularisation. Liquid embolic agents such as N-butyl cyanoacrylate (NBCA) and Onyx provide better visualisation and control than particulate elements.[24] However, some authors suggest that liquid embolic agents may provide less efficient tumoural devascularisation because of the insufficient occlusion of the tumoural vascular bed. They argue that, for liquid embolic agents, the best intratumoural penetration is achieved with direct percutaneous tumour puncture.[25-27] For presurgical embolisation, tumoural bed embolisation with particulate elements is often followed by the occlusion of larger arterial feeders with gelatine sponge or coils. Finally, coils have the advantage of being radiopaque and of allowing for better control in terms of their location. However, arterial occlusion is permanent, rather than temporary as with gelatine sponge.[28] The optimal delay between embolisation and surgery is not clearly defined. It should be long enough to obtain efficient tumoural necrosis but not so long that excessive swelling and potential revascularisation result. Kai *et al.*[29] have reported in a series of 42 patients with meningiomas that the optimal delay to obtain maximum tumour softening was 7 to 9 days when using non-absorbable embolic material. A lower complication rate has been observed in pre-operative procedures when a subtotal occlusion is achieved that may nevertheless be sufficient to significantly reduce bleeding and to facilitate surgery.[13] On the other hand, in palliative situations where no curative surgical resection is planned, the embolisation should be more aggressive and based on a multidisciplinary decision evaluating the balance between the clinical benefits for the patients and the risk of complication.

Endovascular techniques for the treatment of intracranial aneurysms treatment are applicable to the management of iatrogenic pseudoaneurysms. Therapeutic options include conservative management, parent artery occlusion with detachable coils (Figure 2) or balloons and selective aneurysm occlusion with preservation of the parent artery. The selective aneurysm occlusion may be achieved with conventional[30] or stent-assisted coiling.[31] Covered stents have also proved successful.[32-34] Alternatively, double uncovered stenting (Figure 2) or flow-diverting stents might be used when coiling of the sac is challenging.

Complications

As with intracranial neuro-interventional procedures, embolisation in the cervicofacial region should be performed by interventional neuroradiologists with a thorough knowledge and understanding of this complex vascular anatomy. Indeed, rare but potentially serious neurological complications may occur. Non-target embolisation in the territory of the ECA may cause ischaemic injury to lower cranial nerves when tumoural arterial feeders include the ascending pharyngeal artery, the middle meningeal artery or the posterior auricular artery. Moreover, there are many anastomoses between the ECA territory and the ICA, VA and ophthalmic artery.[35] They may initially be patent or open during embolisation because of haemodynamic changes. Pre-, per- and post-procedural angiographic controls must be obtained to identify these dangerous collateral pathways. Tumoural feeders may also arise from the ICA, mainly in skull base meningiomas fed by the mengohypophyseal trunk or the inferolateral trunk. In such cases, there is a risk of reflux in the ICA during embolisation.[13] Non-target embolisation has also been described during percutaneous tumoural embolisation, secondary to the transtumoural passage of embolic material. Temporary balloon occlusion provides protection against the reflux of embolic material in normal arteries during both percutaneous and transarterial procedures.[24,36] Another complication relating to extensive embolisation in the ECA territory is facial skin or mucosal necrosis. Post-embolisation tumour swelling may occur. A pre-existing intracranial mass effect may be exacerbated. If the tumour involves the pharyngeal region, the airway could be compromised so the patient is kept under sedation. Pre- and per-procedure steroid medication may be considered to limit tumour swelling. Finally, when large paragangliomas are embolised, vasoactive peptides may be released and cause a potentially lethal hypertensive response. In

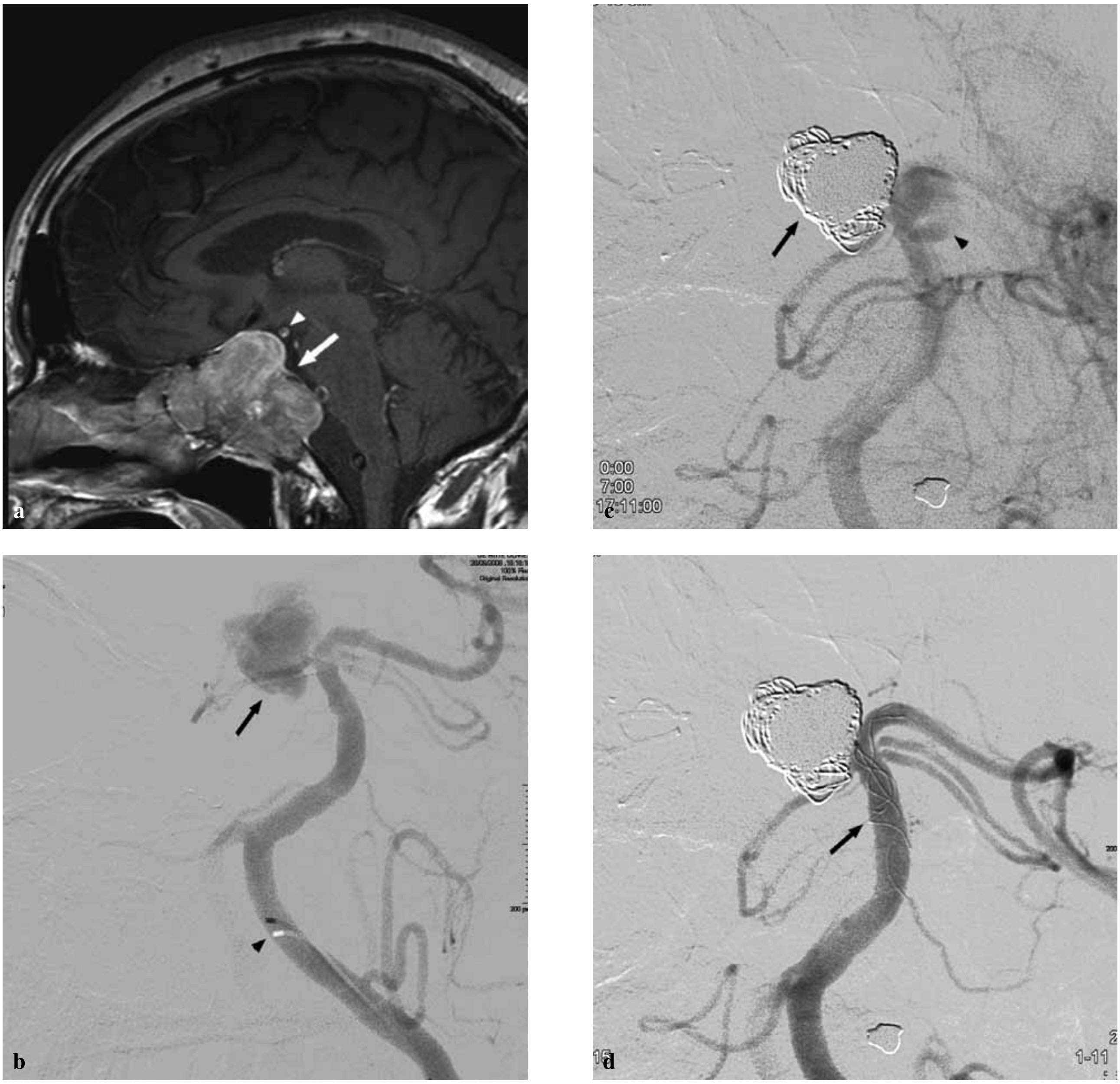

Figure 2

Basilar artery traumatic pseudoaneurysms in a 63-year-old man surgically treated for a hypohyseal adenoma.

a) Pre-operative magnetic resonance imaging: gadolinium-enhanced sagittal T1-weighted image shows a large hypohyseal adenoma (arrow). Note the close relationship with the basilar artery (arrowhead).
b) Emergency conventional angiography of the left vertebral artery shows a large pseudoaneurysm of the basilar tip (arrow). Embolisation with platinum coils was performed to occlude the lesion. The arrowhead shows the coiling microcatheter in the left vertebral artery.
c) Angiographic control at the end of the procedure shows a complete occlusion of the first pseudoaneurysm (arrow) but also reveals a second contrast material leakage (arrowhead).
d) Endovascular treatment of this second pseudoaneurysm was achieved by placing two stents (arrow) in front of the lesion to promote spontaneous thrombosis. Complete occlusion was achieved at the end of the procedure.

hypertensive patients with tumoural secretion of vannilyl-mandellic acid and catecholamines, intra-procedural and intra-operative administration of alpha-blockading agents should be performed.

Conclusion

Neuro-endovascular diagnostic and therapeutic procedures constitute useful adjunctive techniques for surgery involving skull base tumours. The indication for such pre-operative or palliative embolisation should be based on a multi-disciplinary discussion. These techniques should be performed by experienced interventional neuroradiologists with a thorough knowledge of the vascular anatomy of the head and neck in order to avoid rare but potentially serious complications.

References

1. Engelhard HH. Progress in the diagnosis and treatment of patients with meningiomas. Part I: diagnostic imaging, preoperative embolization. *Surg Neurol*. 2001;55(2):89-101.
2. Hu WY, TerBrugge KG. The role of angiography in the evaluation of vascular and neoplastic disease in the external carotid artery circulation. *Neuroimaging Clin N Am*. 1996;6(3): 625-644.
3. Liu DG, Ma XC, Li BM, Zhang JG. Clinical study of preoperative angiography and embolization of hypervascular neoplasms in the oral and maxillofacial region. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod*. 2006;101(1):102-109.
4. Ciceri EF, Regna-Gladin C, Erbetta A, Chiapparini L, Nappini S, Savoiardo M, Di Meco F. Iatrogenic intracranial pseudoaneurysms: neuroradiological and therapeutical considerations, including endovascular options. *Neurol Sci*. 2006;27(5):317-322.
5. Rosen CL, Ammerman JM, Sekhar LN, Bank WO. Outcome analysis of preoperative embolization in cranial base surgery. *Acta Neurochir (Wien)*. 2002;144(11): 1157-1164.
6. Cooke D, Ghodke B, Natarajan SK, Hallam D. Embolization in the head and neck. *Semin Intervent Radiol*. 2008;25(3):293-309.
7. van den Berg R. Imaging and management of head and neck paragangliomas. *Eur Radiol*. 2005;15(7): 1310-1318.
8. Ramina R, Maniglia JJ, Fernandes YB, Paschoal JR, Pfeilsticker LN, Coelho Neto M. Tumors of the jugular foramen: diagnosis and management. *Neurosurgery*. 2005;57(1 Suppl):59-68.
9. Zeitler DM, Glick J, Har-El G. Preoperative embolization in carotid body tumor surgery: is it required? *Ann Otol Rhinol Laryngol*. 2010; 119(5):279-283.
10. Bendszus M, Rao G, Burger R, Schaller C, Scheinemann K, Warmuth-Metz M, Hofmann E, Schramm J, Roosen K, Solymosi L. Is there a benefit of preoperative meningioma embolization? *Neurosurgery*. 2000; 47(6):1306-1311; discussion 1311-1312.
11. Dowd CF, Halbach VV, Higashida RT. Meningiomas: the role of preoperative angiography and embolization. *Neurosurg Focus*. 2003;15(1):E10.
12. Dean BL, Flom RA, Wallace RC, Khayata MH, Obuchowski NA, Hodak JA, Zabramski JM, Spetzler RF. Efficacy of endovascular treatment of meningiomas: evaluation with matched samples. *AJNR Am J Neuroradiol*. 1994;15(9):1675-1680.
13. Waldron JS, Sughrue ME, Hetts SW, Wilson SP, Mills SA, McDermott MW, Dowd CF, Parsa AT. Embolization of skull base meningiomas and feeding vessels arising from the internal carotid circulation. *Neurosurgery*. 2011;68(1):162-169; discussion 169.
14. Persky MS, Setton A, Niimi Y, Hartman J, Frank D, Berenstein A. Combined endovascular and surgical treatment of head and neck paragangliomas – a team approach. *Head Neck*. 2002;24(5):423-431.
15. Murphy TP, Brackmann DE. Effects of preoperative embolization on glomus jugulare tumors. *Laryngoscope*. 1989;99(12):1244-1247.
16. Tasar M, Yetiser S. Glomus tumors: therapeutic role of selective embolization. *J Craniofac Surg*. 2004;15(3): 497-505.
17. Roche PH, Paris J, Regis J, Moulin G, Zanaret M, Thomassin JM, Pellet W. Management of invasive juvenile nasopharyngeal angiofibromas: the role of a multimodality approach. *Neurosurgery*. 2007;61(4):768-777; discussion 777.
18. Fountas KN, Kapsalaki E, Kassam M, Feltes CH, Dimopoulos VG, Robinson JS, Smith JR. Management of intracranial meningeal hemangiopericytomas: outcome and experience. *Neurosurg Rev*. 2006;29(2):145-153.
19. Mathis JM, Barr JD, Jungreis CA, Yonas H, Sekhar LN, Vincent D, Pentheny SL, Horton JA. Temporary balloon test occlusion of the internal carotid artery: experience in 500 cases. *AJNR Am J Neuroradiol*. 1995;16(4): 749-754.
20. Chen YF, Lo YC, Lin WC, Lin CH, Chiang HJ, Chen JF, Shen WC. Transarterial embolization for control of bleeding in patients with head and neck cancer. *Otolaryngol Head Neck Surg*. 2010;142(1):90-94.
21. Laurent A, Wassef M, Chapot R, Houdart E, Merland JJ. Location of vessel occlusion of calibrated tris-acryl gelatin microspheres for tumor and arteriovenous malformation embolization. *J Vasc Interv Radiol*. 2004;15(5):491-496.
22. Laurent A, Wassef M, Chapot R, Wang Y, Houdart E, Feng L, Tran Ba Huy P, Merland JJ. Partition of calibrated tris-acryl gelatin microspheres in the arterial vasculature of embolized nasopharyngeal angiofibromas and paragangliomas. *J Vasc Interv Radiol*. 2005;16(4):507-513.
23. Schroth G, Haldemann AR, Mariani L, Remonda L, Raveh J. Preoperative embolization of paragangliomas and angiofibromas. Measurement of intratumoral arteriovenous shunts. *Arch Otolaryngol Head Neck Surg*. 1996; 122(12):1320-1325.
24. Abdel Kerim A, Bonneville F, Jean B, Cornu P, LeJean L, Chiras J. Balloon-assisted embolization of skull base meningioma with liquid embolic agent. *J Neurosurg*. 2010;112(1):70-72.
25. Elhammady MS, Wolfe SQ, Ashour R, Farhat H, Moftakhar R, Lieber BB, Aziz-Sultan MA. Safety and efficacy of vascular tumor embolization using Onyx: is angiographic devascularization sufficient? *J Neurosurg*. 2010; 112(5):1039-1045.

26. Ozyer U, Harman A, Yildirim E, Aytekin C, Akay TH, Boyvat F. Devascularization of head and neck paragangliomas by direct percutaneous embolization. *Cardiovasc Intervent Radiol*. 2010;33(5):967-975.
27. Chaloupka JC, Mangla S, Huddle DC, Roth TC, Mitra S, Ross DA, Sasaki CT. Evolving experience with direct puncture therapeutic embolization for adjunctive and palliative management of head and neck hypervascular neoplasms. *Laryngoscope*. 1999;109(11):1864-1872.
28. Abada HT, Golzarian J. Gelatine sponge particles: handling characteristics for endovascular use. *Tech Vasc Interv Radiol*. 2007;10(4):257-260.
29. Kai Y, Hamada J, Morioka M, Yano S, Todaka T, Ushio Y. Appropriate interval between embolization and surgery in patients with meningioma. *AJNR Am J Neuroradiol*. 2002;23(1): 139-142.
30. Lempert TE, Halbach VV, Higashida RT, Dowd CF, Urwin RW, Balousek PA, Hieshima GB. Endovascular treatment of pseudoaneurysms with electrolytically detachable coils. *AJNR Am J Neuroradiol*. 1998;19(5):907-911.
31. Kadyrov NA, Friedman JA, Nichols DA, Cohen-Gadol AA, Link MJ, Piepgras DG. Endovascular treatment of an internal carotid artery pseudoaneurysm following transsphenoidal surgery. Case report. *J Neurosurg*. 2002;96(3):624-627.
32. Li MH, Li YD, Gao BL, Fang C, Luo QY, Cheng YS, Xie ZY, Wang YL, Zhao JG, Li Y, Wang W, Zhang BL, Li M. A new covered stent designed for intracranial vasculature: application in the management of pseudoaneurysms of the cranial internal carotid artery. *AJNR Am J Neuroradiol*. 2007;28(8):1579-1585.
33. Yi AC, Palmer E, Luh GY, Jacobson JP, Smith DC. Endovascular treatment of carotid and vertebral pseudoaneurysms with covered stents. *AJNR Am J Neuroradiol*. 2008;29(5): 983-987.
34. Vanninen RL, Manninen HI, Rinne J. Intrasellar Iatrogenic carotid pseudoaneurysm: endovascular treatment with a polytetrafluoroethylene-covered stent. *Cardiovasc Intervent Radiol*. 2003;26(3):298-301.
35. Geibprasert S, Pongpech S, Armstrong D, Krings T. Dangerous extracranial-intracranial anastomoses and supply to the cranial nerves: vessels the neurointerventionalist needs to know. *AJNR Am J Neuroradiol*. 2009;30(8): 1459-1468.
36. Casasco A, Houdart E, Biondi A, Jhaveri HS, Herbreteau D, Aymard A, Merland JJ. Major complications of percutaneous embolization of skull-base tumors. *AJNR Am J Neuroradiol*. 1999;20(1):179-181.

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