

Radiologic-Pathologic Correlation: Hemangioblastoma

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History

A 56-year-old man, with a history of multiple prior abdominal operations, presented for this follow-up screening head MR.

Case Discussion

Findings (see Fig. 1)

Figure 1

A, Sagittal, unenhanced T1-weighted MR

demonstrates a heterogenous mass in the inferior aspect of the cerebellum. There are multiple tubular serpentine signal voids (*arrow*) (SSV) around the periphery of this mass. Although subtle, there is evidence of a prior occipital craniotomy.

B, This gadolinium-enhanced axial T1-weighted MR demonstrates multiple nodular areas of abnormal enhancement. The largest of these is just to the left of the medulla. There are several SSV around the periphery of the large nodule (*arrows*).

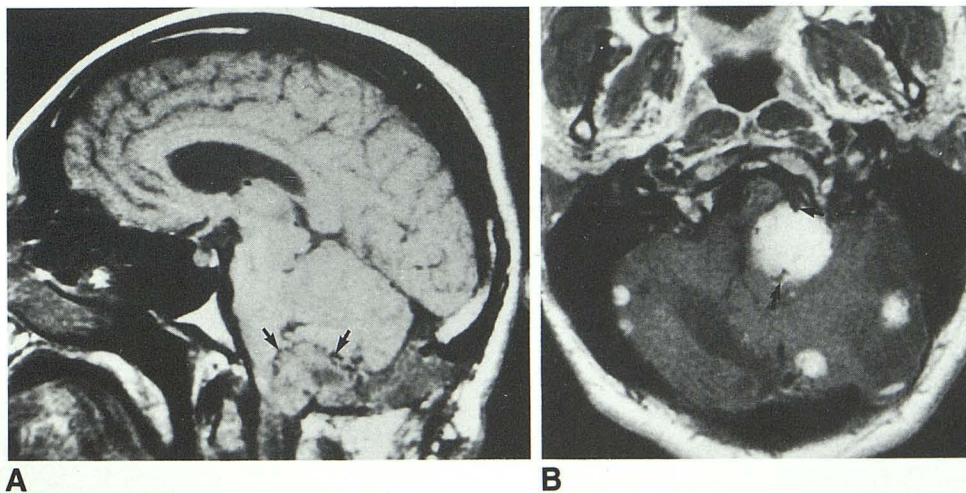


Fig. 1

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Discussion

The differential considerations for a cerebellar lesion in an adult patient include metastasis, hemangioblastoma, cavernous hemangioma, abscess, lobar hemorrhage, and infarction. The hypointensity of the lesion seen on the T1-weighted image (Fig. 1A) and intense pattern of enhancement following gadolinium administration (Fig. 1B) favor metastasis, hemangioblastoma, cavernous hemangioma, and abscess. Multiplicity of lesions, as noted in this case, may be seen with metastasis, hemangioblastoma, cavernous hemangioma, or abscess. The apparent lack of supratentorial lesions would, however, make multiple hemangioblastomas more likely, because metastases or abscesses are both hematogenously disseminated and would most likely also involve the cerebrum if they were multiple, paralleling blood flow. Cavernous hemangiomas, although commonly occurring in multiple locations, are less common than hemangioblastomas in the adult cerebellum. Hemangioblastomas may be the most common primary cerebellar neoplasm in the adult with an incidence at least as common as that of metastasis (1).

The presence of SSV as seen on Figure 1A in the periphery of a lesion is very suggestive of a vascular lesion, especially cerebellar hemangioblastoma. The cavernous hemangioma, although also a vascular lesion, is not usually associated with SSV. A rim of peripheral hypointensity may be seen with a cavernous hemangioma; however, this results from prior hemorrhage and hemosiderin deposition (2).

The detection of the patient's prior craniotomy (Fig. 1B) further supports the diagnosis of hemangioblastomas. Craniotomy is seldom performed for metastasis and rarely for multiple central nervous system (CNS) lesions. Hemangioblastomas, however, are resectable and potentially curable. In this case, the presence of multiple lesions confined to the cerebellum and radiographic evidence of prior tumor removal is very suggestive for multiple hemangioblastomas. The patient's history of prior abdominal operations suggests that the hemangioblastomas are in association with von Hippel-Lindau disease (VHL), a disease with multisystem involvement. In this particular

case, the patient had had bilateral renal cell carcinomas and multiple pancreatic cysts, both manifestations of VHL. He had previously undergone bilateral nephrectomies, cadaveric renal transplant, and numerous drainage procedures for his pancreatic cysts.

Diagnosis

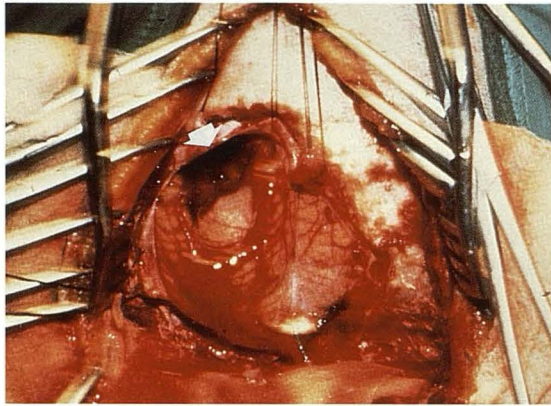
Multiple Hemangioblastomas (in VHL)

Hemangioblastoma

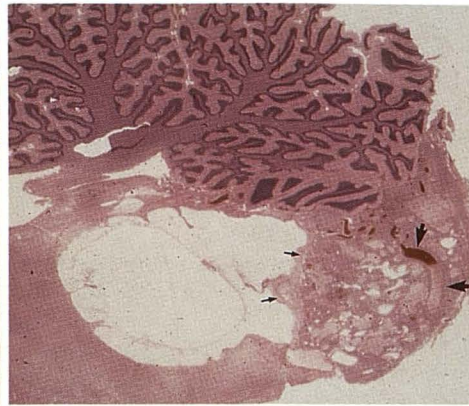
The hemangioblastoma (Lindau tumor, capillary hemangioblastoma, hemangioendothelioma, angioreticuloma, angioblastoma) is a benign tumor of the CNS. These tumors may be predominantly solid or have both solid and cystic areas. Hemangioblastomas account for 1%–2.5% of all intracranial neoplasms (3, 4). Although also found in the spinal cord (3%–13%), medulla (2%–3%) and cerebrum (1.5%), hemangioblastomas most commonly occur in the cerebellum (83%–86%), where they comprise 7%–12% of primary posterior fossa tumors (3–6).

Hemangioblastomas typically present in the third through fifth decades of life; however, they have been reported at all ages ranging from 1–75 years old (3–10). There is a slight male predilection for hemangioblastomas, with male:female ratios ranging from 1.3:1 to 2.6:1 (3, 4, 8, 9, 11).

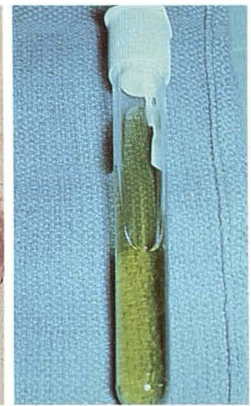
Patients with hemangioblastomas usually have a long history (6–10 months) of minor neurologic symptoms that are often followed by a sudden exacerbation, forcing them to seek medical attention (3, 6–8). The most common presenting symptoms of intracranial hemangioblastomas are headache (70%), disequilibrium (50%), nausea/vomiting (37%), and dizziness/vertigo (26%) (5). On neurologic examination, patients most frequently demonstrate cerebellar signs (38%), papilledema (33%) and nystagmus (20%) (5). At the time of presentation, as many as 50% of patients manifest signs and symptoms of increased intracranial pressure secondary to obstructive hydrocephalus and require emergency treatment (6).



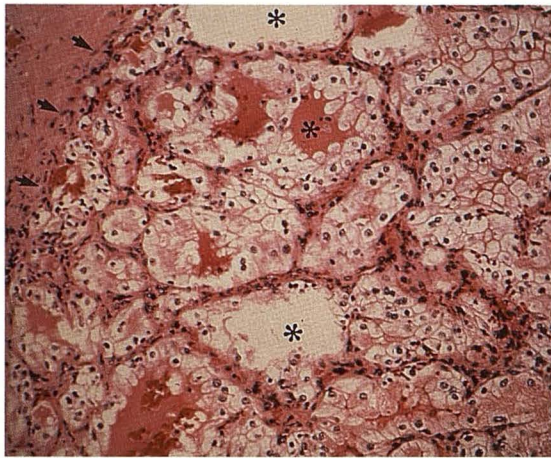
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Fig. 2. Cerebellar hemangioblastoma, operative photograph. The cerebellum has been decorticated, and we are peering into the cyst surrounding the tumor. There is a deep red nodule (arrow) at the upper portion of the lesion that represents the neoplasm itself. The cyst is external to the neoplasm and lined by normal cerebellar tissue.

Fig. 3. Cerebellar hemangioblastoma, subgrossed specimen. This hematoxylineosin-stained specimen illustrates normal cerebellar folia at the top of the photograph. The nodule of the hemangioblastoma is in a subpial location. Within this solid nodule, are numerous large tubular structures representing vascular sinusoids (large arrows). There are pale pink areas representing collections of stromal cells. The nodule is located on the right side of the cyst. Note that the neoplasm does not form the wall of the cyst but rather, the cyst "wall" is composed of compressed normal cerebellar tissue (small arrows).

Fig. 4. Cyst fluid, specimen. This test tube contains the aspirated fluid from a cyst surrounding a hemangioblastoma, demonstrating the typical xanthochromic appearance. The fluid is benign and does not contain neoplastic cells.

Fig. 5. Cerebellar hemangioblastoma, photomicrograph (hematoxylineosin stain, 350X). There is a relatively sharp demarcation between the hemangioblastoma and the adjacent brain (arrows). Most of the field demonstrates pale pink, polygonal, foamy-appearing stromal cells. In between the stromal cells is a lace-like pattern of capillaries lined by plump endothelial cells. There are several "microcysts" or lakes of proteinaceous fluid (asterisks) within the tumor.

Hemangioblastomas may produce polycythemia in some cases. Up to 40% of hemangioblastomas have been reported to secrete erythropoietin (7). The polycythemia usually resolves following resection of the tumor but may return with tumor recurrence. The polycythemia is more commonly associated with solid hemangioblastomas (3, 4, 7, 9, 12, 13).

Pathology

Gross

The hemangioblastoma is typically a well-circumscribed tumor that forms a solid "mural nodule" within a larger cyst cavity (60%) (Figs. 2 and 3). The tumor nodule commonly

abuts the pial surface (Fig. 3). The cyst fluid is often xanthochromic (Fig. 4), but rarely may be rusty brown if hemorrhage into the cyst has occurred (7, 14). The "cyst" around the mural nodule is a collection of fluid and is not truly part of the neoplasm. Therefore, the cyst and its lining need not be resected unless there is evidence of tumor involvement. Less frequently, the hemangioblastoma has no surrounding cyst and is purely solid (40%) (3, 6, 7).

Cumings found the cysts surrounding hemangioblastomas to have amino acid, nitrogen, mucoprotein, and alkaline phosphate levels similar to that of blood, suggesting that the cyst fluid arose by diffusion from the vascular component of the mural nodule (15). Addi-

tionally, the cyst fluid has been found to contain erythropoietin (13). Note that cysts may also occur within a mural nodule or solid tumor; the cysts in this instance are part of the tumor mass (3, 7, 16).

Microscopic

The hemangioblastoma is composed of a cluster of thin-walled, tightly packed blood vessels lined by plump endothelial cells on a

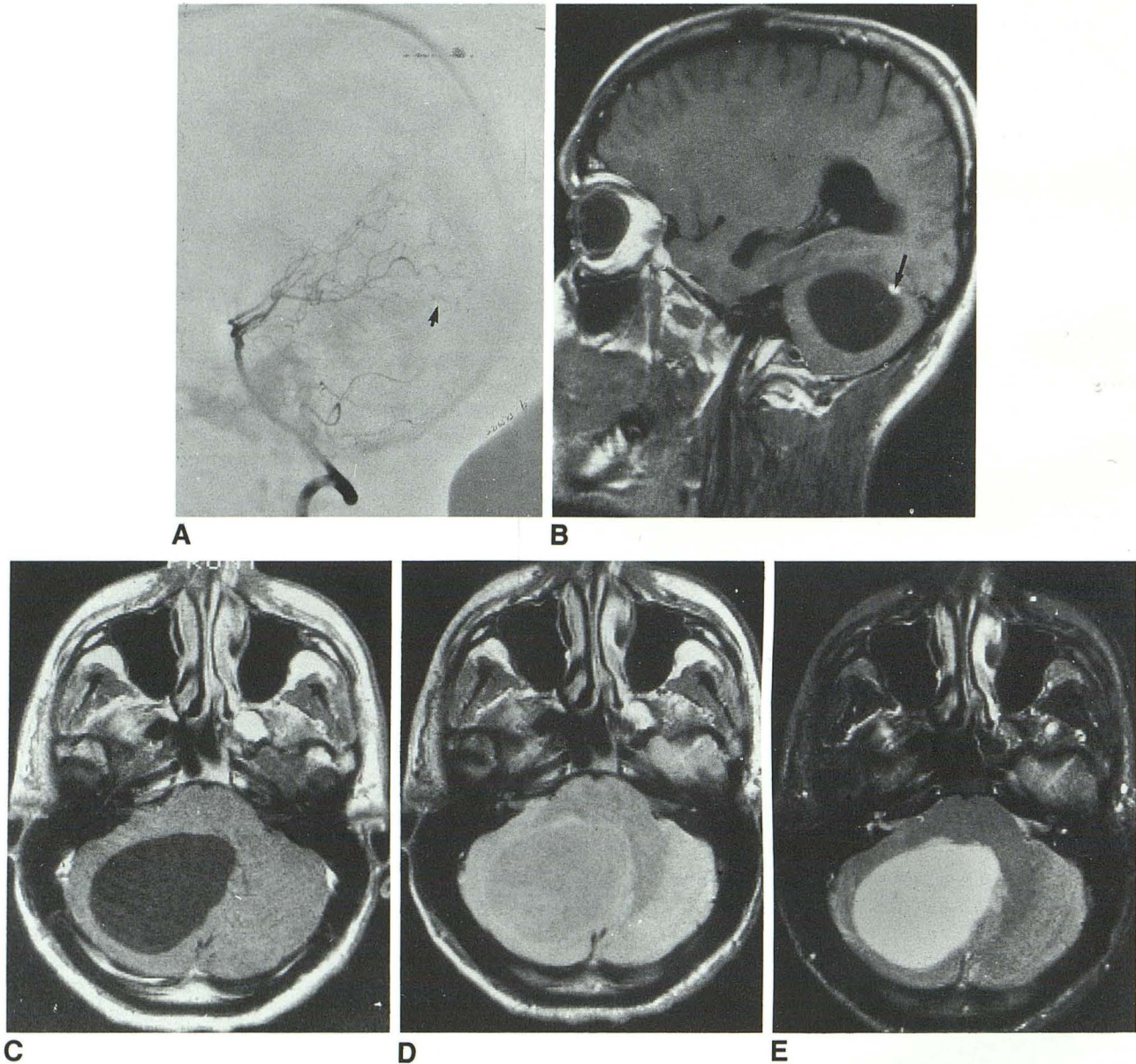


Fig. 6. Cerebellar hemangioblastoma, typical solid nodule with surrounding cyst. A lateral film (A) from a vertebral angiogram demonstrates a faint area of enhancement (*arrow*) corresponding to the nodule seen on the gadolinium-enhanced sagittal T1-weighted MR (B, *arrow*). Note the nodule's subpial location. The remainder of the lining of the cyst is not composed of neoplastic tissue and, therefore, does not enhance. Unenhanced T1-weighted axial MR (C) demonstrates a homogenous "cystic" mass involving most of the cerebellar hemisphere. The cyst fluid is slightly hyperintense compared to CSF. The proton-density image (D) demonstrates an increase in signal intensity of the cyst fluid, which becomes even brighter on the T2-weighted pulse sequence (E).

background of abundant connective tissue (Fig. 5). The blood vessels vary in size from capillary to cavernous and are interspersed with polygonal, lipid-laden "stromal" cells. The cytologic features of the endothelial and stromal cells is usually benign without mitotic figures. Necrosis and hemorrhage may occur, but are uncommon (3, 7, 12, 17).

The cyst wall, if present, is composed of compressed adjacent brain parenchyma or reactive neuroglial cells. This is in distinction to a cyst found within a tumor nodule that is part of the hemangioblastoma which may represent dilated vascular spaces or regions of necrosis within the neoplastic tissue of the hemangioblastoma (3, 7, 12, 17).

Radiology

Angiography

Angiographically, the hemangioblastoma may be identified as a dense tumor nodule (Figs. 6A and 7A) or as a heterogeneous network of tangled vessels fed by a dilated artery (4, 14, 18–20). Dilated draining veins (Fig. 7A) have also been reported (21). If the tumor sits within a cyst, it may appear as a vascular nodule within an avascular region, secondary to displacement of the surrounding vessels by the avascular cyst (Figs. 6A and 7A). Angiog-

raphy continues to be a crucial tool in the evaluation of hemangioblastoma, inasmuch as, in several cases, it has detected tumors not otherwise identified on computed tomography (CT) or magnetic resonance (MR) (11, 22, 23).

CT

On unenhanced CT, the hemangioblastoma most commonly appears as a small isodense nodule within a well-circumscribed, thin-walled hypodense cyst (Figs. 8A and 9A) (17, 19, 21, 22, 24). Following the administration of intravenous contrast, the mural nodule will enhance homogeneously (Figs. 8B and 9B). The cyst wall generally does not enhance (Fig. 8B). Should the wall enhance, neoplastic extension along the cyst wall should be suspected (Fig. 9B) (16). Solid hemangioblastomas are usually isodense but are occasionally hyperdense on precontrast CT, and show prominent homogeneous enhancement (11, 20). Ring enhancement of solid hemangioblastomas has also been reported (20). On CT, the secondary features of hemangioblastoma such as hydrocephalus (Figs. 8A and 8B) and edema are well visualized.

MR

The most common MR patterns (Fig. 10) of hemangioblastoma are the traditionally de-

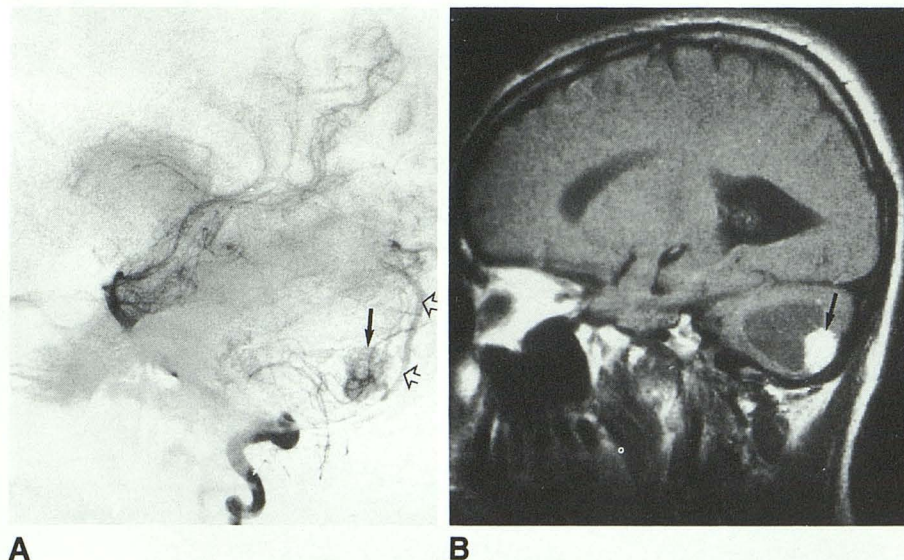


Fig. 7. Cerebellar hemangioblastoma, typical solid nodule with surrounding cyst. The lateral view of a vertebral angiogram (A) demonstrates the vascular tumor nodule (*solid arrow*) in the posterior cerebellum in a relatively avascular region that corresponds to the surrounding cyst. A dilated draining vein is also appreciated on this angiogram (*open arrows*). The relationship of the hemangioblastoma abutting the posterior aspect of the cyst is better appreciated on the gadolinium-enhanced sagittal T1-weighted MR image (B) that illustrates the densely enhancing tumor (*arrow*) within the non-enhancing cyst.

scribed solid "mural nodule" with an adjacent nonenhancing surrounding cyst (Figs. 6B, 7B, 8C, and 8D) (1/3) or purely solid (Figs. 1A, 1B, 11A, and 11B) (1/3) (5, 11). In some cases the tumor may also appear completely "cystic" (without a mural nodule detected on MR, but seen on angiography, CT, or at resection). Sometimes, there will be a mural nodule associated with an enhancing cyst wall (Figs. 9C and 9D), or a solid mass with internal cysts. Overall, roughly 55% of hemangioblastomas have a surrounding cyst and the other 45% are predominantly solid (5, 11). This radiographic distribution correlates well with the pathologic spectra of 60% cystic and 40% solid described by Rubinstein (3).

The typical hemangioblastoma is hypo- to isointense on short T1-weighted MR (Figs. 1A

and 6C) and hyperintense on proton- (Fig. 6D) and T2-weighted MR (Figs. 6E and 11B). Occasionally, hemangioblastomas may be heterogeneous on T1-weighted MR (Fig. 11A), with foci of increased signal intensity seen within the solid portion of the tumor. These regions of T1 signal shortening may represent lipid within stromal cells or methemoglobin from hemorrhage within the tumor (11, 17, 23).

The cyst fluid surrounding the neoplasm will be slightly hyperintense compared to cerebrospinal fluid (CSF) on T1-weighted (Fig. 6C) and proton-weighted images (Fig. 6D) and much more hyperintense on T2-weighted images (Fig. 6E). These characteristics of the fluid are attributable to its high protein content (25, 26).

Following intravenous administration of gadolinium, the neoplastic tissue markedly

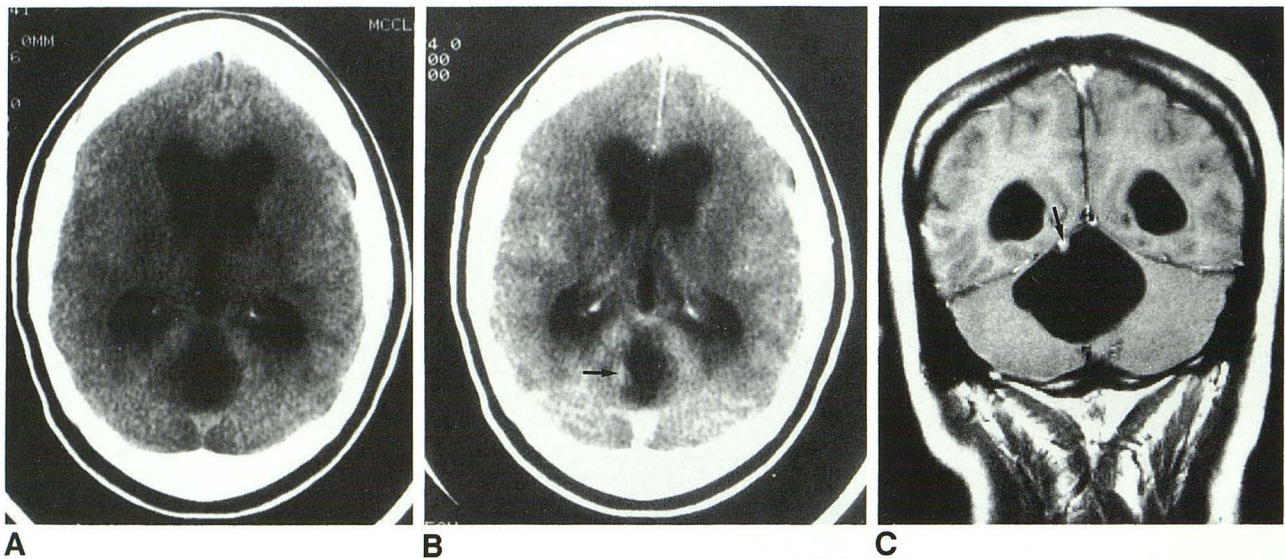
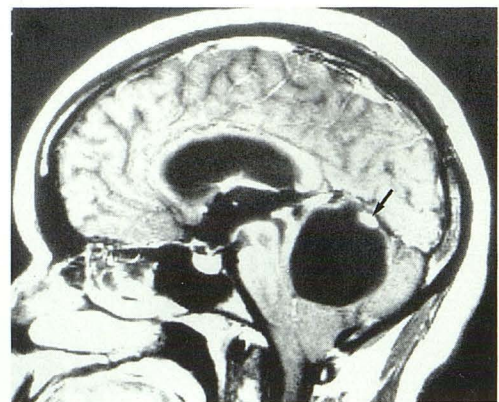


Fig. 8 Cerebellar hemangioblastoma, typical solid nodule with surrounding cyst. A "cystic" mass is noted in the area of the cerebellar vermis on the noncontrast CT scan (A). Following contrast infusion, a faint nodule of enhancement is seen along the right lateral border of this cystic mass (B, arrow). T1-weighted MR after gadolinium infusion in the coronal (C) and sagittal (D) planes illustrate only a small nodule (arrows) of enhancement. Again, this nodule is in a subpial location and the majority of the tissue lining the cyst does not enhance and is not composed to neoplastic tissue.



D

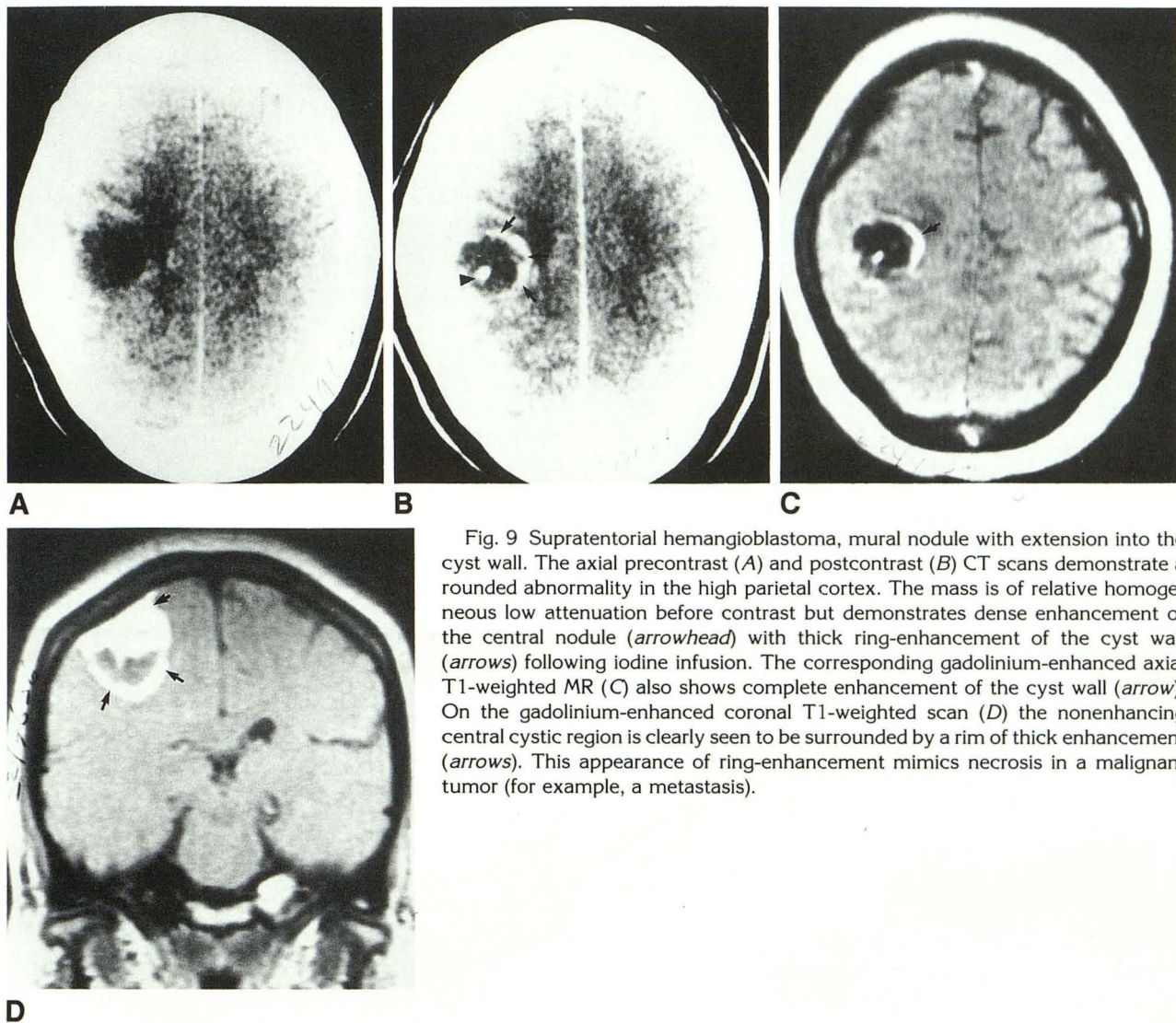


Fig. 9 Supratentorial hemangioblastoma, mural nodule with extension into the cyst wall. The axial precontrast (A) and postcontrast (B) CT scans demonstrate a rounded abnormality in the high parietal cortex. The mass is of relative homogeneous low attenuation before contrast but demonstrates dense enhancement of the central nodule (arrowhead) with thick ring-enhancement of the cyst wall (arrows) following iodine infusion. The corresponding gadolinium-enhanced axial T1-weighted MR (C) also shows complete enhancement of the cyst wall (arrow). On the gadolinium-enhanced coronal T1-weighted scan (D) the nonenhancing central cystic region is clearly seen to be surrounded by a rim of thick enhancement (arrows). This appearance of ring-enhancement mimics necrosis in a malignant tumor (for example, a metastasis).

enhances (Figs. 1B, 6B, 7B, 8C, 8D, 9C, and 9D). Because of the high signal intensity of the surrounding cyst fluid on proton- and T2-weighted MR images, the tumor nidus is usually better visualized on gadolinium-enhanced T1-weighted sequences (compare Fig. 6B to Fig. 6E). As seen on contrast-enhanced CT, the cyst wall usually does not enhance (Figs. 6B, 7B, 8C, and 8D). However, if the cyst is lined by neoplasm, the wall will enhance (Figs. 9C and 9D) (11, 19, 23, 25, 27).

On MR, hemangioblastomas commonly (60%–69%) have associated internal and/or peripheral SSV (Figs. 1A, 11A, and 11B), consistent with the dilated afferent and efferent

vessels (11, 23, 27, 28) identified pathologically. In fact, according to Lee et al, “the association of a peripheral cyst in the posterior fossa with a mural nodule supplied by enlarged vessels is virtually pathognomonic for hemangioblastoma” (23).

Overall, MR is more sensitive than CT in the detection of hemangioblastomas (11, 19, 23, 27, 28). MR, in addition, to the benefit of detecting SSV (Figs. 1A, 11A, and 11B), is multiplanar and allows for sagittal (Figs. 1A, 6B, 7B, and 8D) and coronal (Figs. 8C and 9D) imaging that help identify small peripheral mural nodules in some cases. MR is also better at imaging the posterior fossa and does not suffer

the effects of beam hardening and other artifacts commonly noted with CT.

Associations

Hemangioblastomas may be inherited as solitary or multiple lesions or may occur in conjunction with additional visceral tumors as part of VHL (3). VHL is a hereditary disorder with an autosomal dominant mode of transmission and a greater than 90% penetrance (29). VHL has been linked to a defect on chromosome 3 (30). The diagnosis of VHL may be established by the presence of 1) more than one CNS (including retinal) hemangioblastoma, 2) one

CNS hemangioblastoma with a visceral manifestation of VHL (Table 1), or 3) one manifestation of VHL with a known family history (10, 25, 31–34). In Huson et al's series of 35 patients with VHL, cerebellar hemangioblastomas (83%), pancreatic cysts (69%), renal cell carcinoma (51%), renal cysts (49%), and retinal hemangioblastoma (46%) were the most common features noted at autopsy (10).

Solitary hemangioblastomas are associated with VHL in 4%–40% of cases (average of 10%–20%) (3–6, 8, 10). The age of presentation of hemangioblastoma in VHL is usually one to two decades earlier than that of the sporadic variety (6, 10, 32). The male:female ratio of hemangioblastomas in VHL is closer to 1:1 (32).

Prognosis

The prognosis for cerebellar hemangioblastoma is quite good, with 85% of patients surviving 5–20 years following surgical removal of the tumor (3). The perioperative mortality is between 7%–15% and related to postoperative hemorrhage or increased intracranial pressure (4, 6). Medullary hemangioblastomas have a higher rate of morbidity (40%) (9). Spinal hemangioblastomas, which are frequently associated with subarachnoid bleeding at presentation, also have an increased morbidity (6). Solid hemangioblastomas have been reported to have a higher incidence of complications (9, 20). Young and Richardson, in their series of

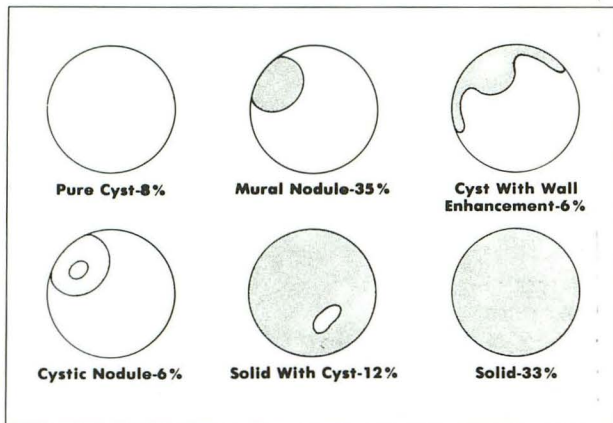


Fig. 10. Radiologic patterns of hemangioblastoma. There are six morphologic types of hemangioblastoma as visualized on MR and CT. (Modified from Murphy et al (5).)

Fig. 11. Cerebellar hemangioblastoma, purely solid. This solid hemangioblastoma is seen on the unenhanced T1-weighted (A) and T2-weighted (B) pulse sequences. On the T1-weighted image, there is a heterogeneous solid mass involving the left cerebellar hemisphere. Portions of this mass have areas of focal hyperintensity (arrows). There are also multiple curvilinear serpentine signal avoids (SSV) around the periphery. On the T2-weighted image (B), most of the nodule has become hyperintense, except for the curvilinear SSV (arrows).

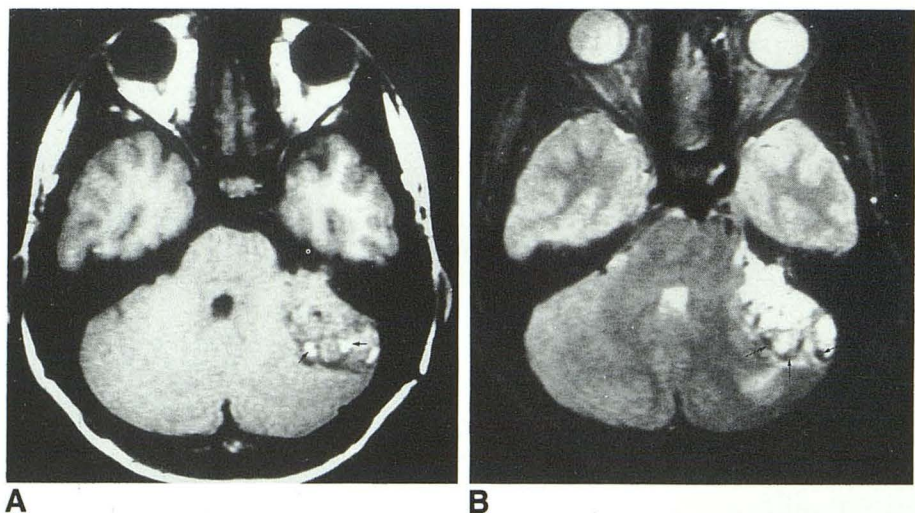


TABLE 1: Manifestations of von Hippel-Lindau disease*

CNS	Hemangioblastoma (cerebellum, eye, medulla, spinal cord, cerebellum) Meningioma
Kidney	Renal cell carcinoma (often cystic) Cyst Hemangioblastoma Hemangioma Adenoma
Pancreas	Cyst Cystadenoma Islet cell tumor Carcinoma Hemangioblastoma Hemangioma
Adrenal	Pheochromocytoma Adenoma Cyst Cortical hyperplasia
Liver	Cyst Adenoma Hemangioma Hemangioblastoma
Spleen	Hemangioma
Lung	Cyst Hemangioblastoma
Bladder	Hemangioblastoma
Epididymis	Cyst Hypernephroid tumor Cystadenoma ^b
Sympathetic chain	Paraganglioma

* Modified from References 25 and 31–36.

^b Cystadenoma may also occur in the broad ligament in female patients.

14 solid hemangioblastomas, reported a 50% rate of death or “poor result” postoperatively (20). Patients with VHL may have a graver prognosis, but perhaps secondary to the other associated conditions, especially that of renal cell carcinoma (32, 33).

The overall recurrence rate for hemangioblastomas ranges from 8%–16% (4, 9, 32). The recurrent tumor may not necessarily have the same morphology as the original tumor. Solid hemangioblastomas may recur as cystic tumors and vice versa (4).

References

- Martin F, Lemmen LJ. Calcification in intracranial neoplasms. *Am J Pathol* 1952;28:1107–1131
- Rapacki TFX, Brantley MJ, Furlow TW, Geyer CA, Toro VE, George ED. Heterogeneity of cerebral cavernous hemangiomas diagnosed by MR imaging. *J Comput Assist Tomogr* 1990;14:18–25
- Rubinstein LJ. *Tumors of the central nervous system*. 2nd series, Fascicle 6. Washington, DC: Armed Forces Institute of Pathology, 1972:235–241
- Mondkar VP, McKissock W, Russell RWR. Cerebellar hemangioblastomas. *Br J Surg* 1967;54:45–49
- Murphy FM, Smirniotopoulos JG, Parisi J. Hemangioblastoma: radiologic-pathologic correlation. Paper presented at the 87th Annual Meeting of the American Roentgen Ray Society, 1987
- Neumann HPH, Eggert HR, Weigel K, Friedburg H, Wiestler OD, Schollmeyer. Hemangioblastomas of the central nervous system: a 10-year study with special reference to von Hippel-Lindau syndrome. *J Neurosurg* 1989;70:24–30
- Silver ML, Hennigar G. Cerebellar hemangioma (hemangioblastoma): a clinicopathological review of 40 cases. *J Neurosurg* 1952;9:484–489
- Jeffreys R. Clinical and surgical aspects of posterior fossa hemangioblastoma. *J Neurol Neurosurg Psychiatry* 1976;38:105–111
- Constans JP, Meder F, Maiuri F, Donzelli R, Spaziante R, de Divitiis E. Posterior fossa hemangioblastomas. *Surg Neurol* 1986;25:269–275
- Huson SM, Harper PS, Hourihan MD, Cole G, Weeks RD, Compston DAS. Cerebellar hemangioblastoma and von Hippel-Lindau disease. *Brain* 1986;109:1297–1310
- Smirniotopoulos JG, Murphy FM, Brown DC. MR imaging of hemangioblastoma. *Radiology* 1989;173(P):85
- Jeffreys R. Pathological and hematological aspects of posterior fossa hemangioblastoma. *J Neurol Neurosurg Psychiatry* 1975;38:112–119
- Waldmann TA, Levin EH, Baldwin M. The association of polycythemia with a cerebellar hemangioblastoma: the production of an erythropoiesis stimulating factor by the tumor. *Am J Med* 1961;31:318–324
- Coulam CM, Brown LR, Reese DF. Hippel-Lindau syndrome. *Semin Roentgenol* 1976;11:61–66
- Cummings JN. The chemistry of cerebral cysts. *Brain* 1950;73:244–250
- Maiuri F. Cysts with mural tumor nodules in the cerebral hemispheres. *Neurosurgery* 1988;22:703–706
- Tan WS, Wilbur A, Spigos DG, Choi KH. Cystic mural nodule in cerebellar hemangioblastoma: CT demonstration. *J Comput Assist Tomogr* 1984;8:1175–1178
- Wolpert SM. The neuroradiology of hemangioblastomas of the cerebellum. *AJR* 1970;110:56–66
- Filling-Katz MR, Choyke PL, Patronas NJ, Gorin MB, Barba D, Chang R, Doppman JL, Seizinger B, Oldfield EH. Radiologic screening for von Hippel-Lindau disease: the role of Gd-DTPA enhanced MR imaging of the CNS. *J Comput Assist Tomogr* 1989;13:743–755
- Young S, Richardson AE. Solid hemangioblastomas of the posterior fossa: radiological features and results of surgery. *J Neurol Neurosurg Psychiatry* 1987;50:155–158
- Pinto JA, Pereira JR, Guimaraes A, Veiga-Pires JA. The value of CT-scanning in supratentorial hemangioblastomas. *Neuroradiology* 1987;29:573–575

22. O'Reilly GV, Rumbaugh CL, Bowens M, Kido DK, Naheedy MH. Supratentorial haemangioblastoma: the diagnostic roles of computed tomography and angiography. *Clin Radiol* 1980;32:389-392
23. Lee SR, Sanches J, Mark AS, Dillon WP, Norman D, Newton TH. Posterior fossa hemangioblastomas: MR imaging. *Radiology* 1989;171:463-468
24. Ganti SR, Silver AJ, Hilal SK, Mawad ME, Sane P. Computed tomography of cerebellar hemangioblastoma. *J Comput Assist Tomogr* 1982;6:912-919
25. Braffman BH, Bilaniuk LT, Zimmerman RA. MR of central nervous system neoplasia of the phakomatoses. *Semin Roentgenol* 1990;25:198-217
26. Kjos BO, Brant-Zawadzki M, Kucharczyk W, Kelly WM, Norman D, Newton TH. Cystic intracranial lesions: magnetic resonance imaging. *Radiology* 1985;155:363-369
27. Sato Y, Waziri M, Smith W, et al. Hippel-Lindau disease: MR imaging. *Radiology* 1988;166:241-246
28. Pont MS, Elster AD. Lesions of skin and brain: modern imaging of the neurocutaneous syndromes. *AJR* 1992;158:1193-1203
29. Go RCP, Lamiell JM, Hsia YE, Yuen JWM, Paik Y. Segregation and linkage analyses of von Hippel-Lindau disease among 220 descendants from one kindred. *Am J Human Genet* 1984;36:131-142
30. Hosoe S, Brauch H, Latiff F, et al. Localization of the von Hippel-Lindau disease to a small region of chromosome 3. *Genomics* 1990;8:634-640
31. Melmon KL, Rosen SW. Lindau's disease: review of the literature and study of a large kindred. *Am J Med* 1964;36:595-617
32. Michels VV. Von Hippel-Lindau disease. In: Gomez MR, ed. *Neurocutaneous diseases: a practical approach*. Boston: Butterworth, 1987:53-66
33. Horton WA, Wong V, Eldridge R. Von Hippel-Lindau disease: clinical and pathological manifestations in nine families with 50 affected members. *Arch Intern Med* 1976;136:769-777
34. Lee KR, Wulfsberg E, Kepes JJ. Some important radiological aspects of the kidney in Hippel-Lindau syndrome: the value of prospective study in an affected family. *Radiology* 1977;122:649-653
35. Funk KC, Heiken JP. Papillary cystadenoma of the broad ligament in a patient with von Hippel-Lindau disease. *AJR* 1989;153:527-528
36. McGrath FP, Gibney RG, Morris DC, Owen DA, Erb SR. Case report: multiple hepatic and pulmonary hemangioblastomas—a new manifestation of von Hippel-Lindau disease. *Clin Radiol* 1992;45:37-39