Acta Neurochirurgica (2019) 161:1191–1195
https://doi.org/10.1007/s00701-019-03840-5

CASE REPORT - VASCULAR NEUROSURGERY - ANEURYSM

Internal carotid artery aneurysms diagnosed after stereotactic radiosurgery for a growth hormone-secreting pituitary adenoma: a case report and literature review

Hirotaka Inoue[1] · Takayuki Kawano[1] · Yuki Ohmori[1] · Toshihiro Amadatsu[1] · Haruaki Yamamoto[2] · Toru Nishi[2] · Akitake Mukasa[1]

Received: 7 September 2018 / Accepted: 8 February 2019 / Published online: 6 April 2019
© Springer-Verlag GmbH Austria, part of Springer Nature 2019

Abstract

Radiation therapy is associated with the subsequent development of cerebral aneurysms; however, stereotactic radiosurgery (SRS)-associated aneurysm cases have not been well documented, with only 18 cases reported to date. We present a case of intracranial aneurysms with the rupture occurring 20 years after SRS for a growth hormone-producing pituitary adenoma. This is the first report of aneurysms diagnosed following transsphenoidal surgery and SRS for pituitary adenoma. We believe that the aneurysm reported here is a consequence of the SRS treatment, and thus this may be a very rare long-term complication following radiation treatments.

Keywords Aneurysm · Stereotactic radiosurgery · Gamma knife · Pituitary adenoma

Abbreviations

AVM	Arteriovenous malformation
ECA	External carotid artery
GHoma	Growth hormone-producing pituitary adenoma
GKS	Gamma knife surgery
ICA	Internal carotid artery
MCA	Middle cerebral artery
MRI	Magnetic resonance imaging
SRS	Stereotactic radiosurgery
STA	Superficial temporal artery
TSS	Transsphenoidal surgery

This article is part of the Topical Collection on *Vascular Neurosurgery-Aneurysm*

Electronic supplementary material The online version of this article (https://doi.org/10.1007/s00701-019-03840-5) contains supplementary material, which is available to authorized users.

✉ Takayuki Kawano
tkawano-nsu@umin.net

[1] Departments of Neurosurgery, Graduate School of Medical Sciences, Kumamoto University, 1-1-1 Honjo Chuo-ku, Kumamoto 860-8556, Japan

[2] Department of Neurosurgery, Saiseikai Kumamoto Hospital, Kumamoto, Japan

Introduction

Stereotactic radiosurgery (SRS), including gamma knife surgery (GKS), is an established treatment for brain tumours, arteriovenous malformations (AVM), and trigeminal neuralgia. Although radiation is known to be associated with the subsequent development of aneurysms [14], only 18 cases of aneurysm formation after SRS have been reported to date [1, 2, 5–10, 12, 13, 16–20].

Here, we present a case of ruptured intracranial aneurysms after SRS for growth hormone-producing pituitary adenoma (GHoma). To the best of our knowledge, this is the first report of aneurysms developed after transsphenoidal surgery (TSS) and SRS for pituitary adenoma.

Case report

A 41-year-old man underwent TSS for GHoma removal at our hospital. The adenoma had progressed around the right internal carotid artery (ICA); we performed partial removal to avoid injury to the ICA (Fig. 1). Three months later, GKS was performed for the residual tumour (Fig. 2a). The prescription dose to the target volume was 35 Gy to the 50% isodose line. To avoid injury to the optic pathway, we demarcated the area to be irradiated such that the tumour adjoining the optic

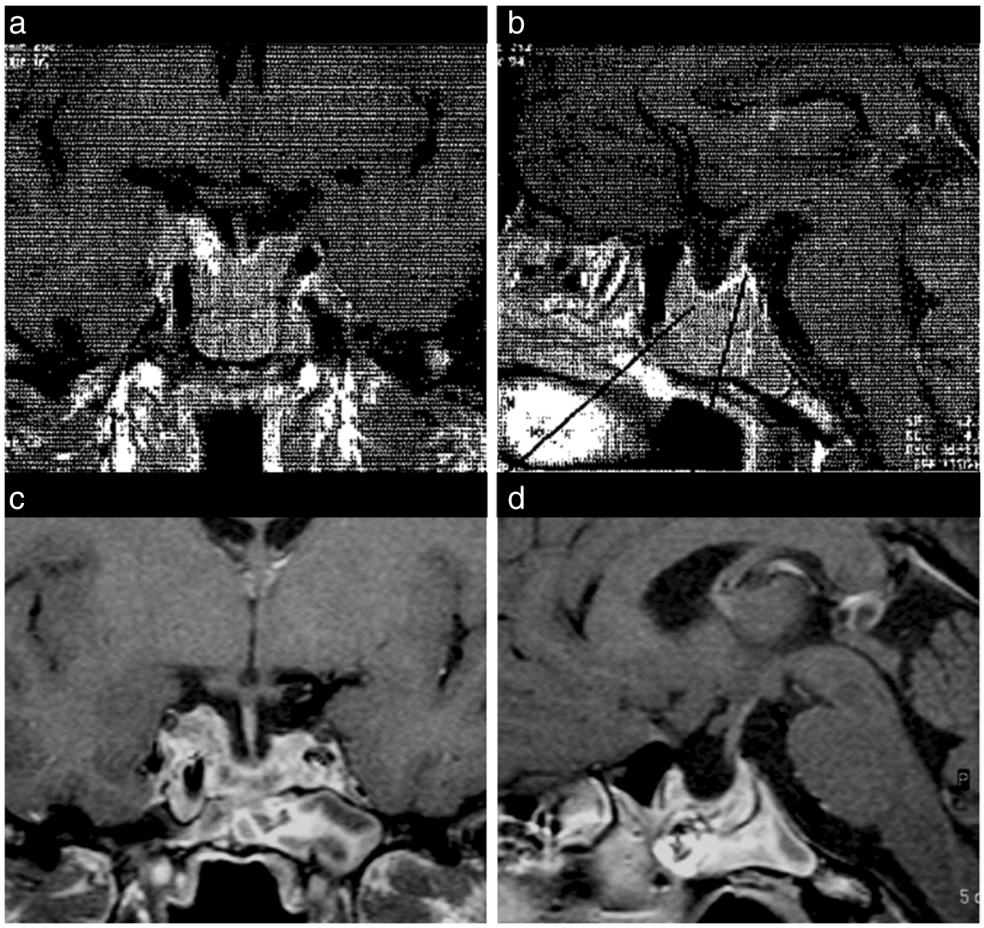

Fig. 1 **a** Preoperative MR image (T1 weighted with Gd, coronal view) showing a mass lesion from the sella to the sphenoid sinus and right cavernous sinus. **b** Preoperative MR image (T1 weighted with Gd, sagittal view). **c** Postoperative MR image (T1 weighted with Gd, coronal view) showing the residual tumour in the right cavernous sinus. **d** Postoperative MR image (T1 weighted with Gd, sagittal view)

pathway was precisely included. Fortunately, no visual field deficits were observed after GKS.

Twenty years after GKS, the patient experienced acute-onset epistaxis. He was examined by an otolaryngologist at an emergency hospital; however, the source of the bleeding could not be determined. The bleeding continued, resulting in hypotension. Subsequently, he went into shock and was admitted. Endoscopic examination confirmed the bleeding in the sphenoid sinus, which had been opened at the time of TSS (Fig. 3a), and he was referred to our department. Computed tomography, magnetic resonance imaging (MRI), and angiography revealed two aneurysms in the right ICA, which

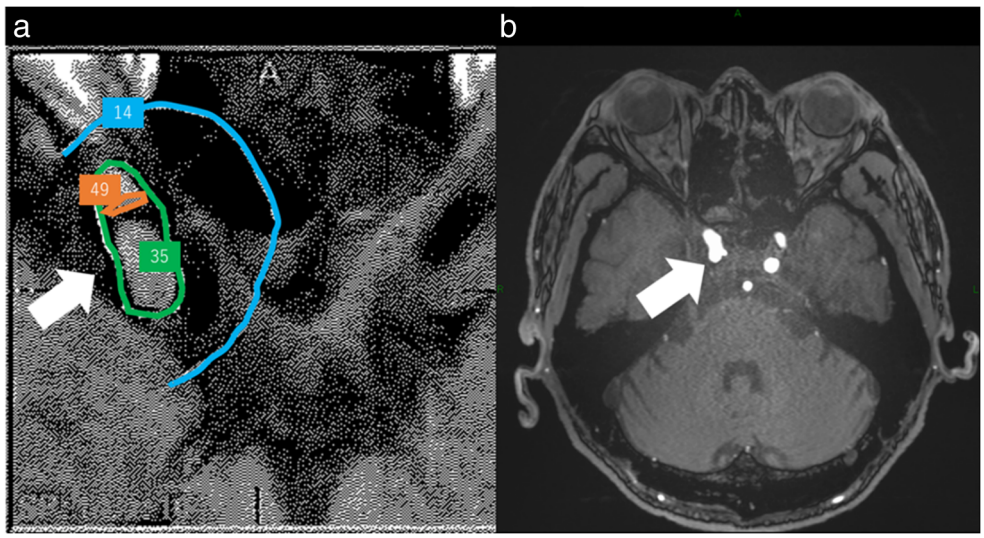

Fig. 2 **a** Gamma knife-plan image of the residual tumour (the numbers indicate each value of Gy). **b** Magnetic resonance angiography image of the aneurysm in the right internal carotid artery. The two positions (arrows) are almost identical

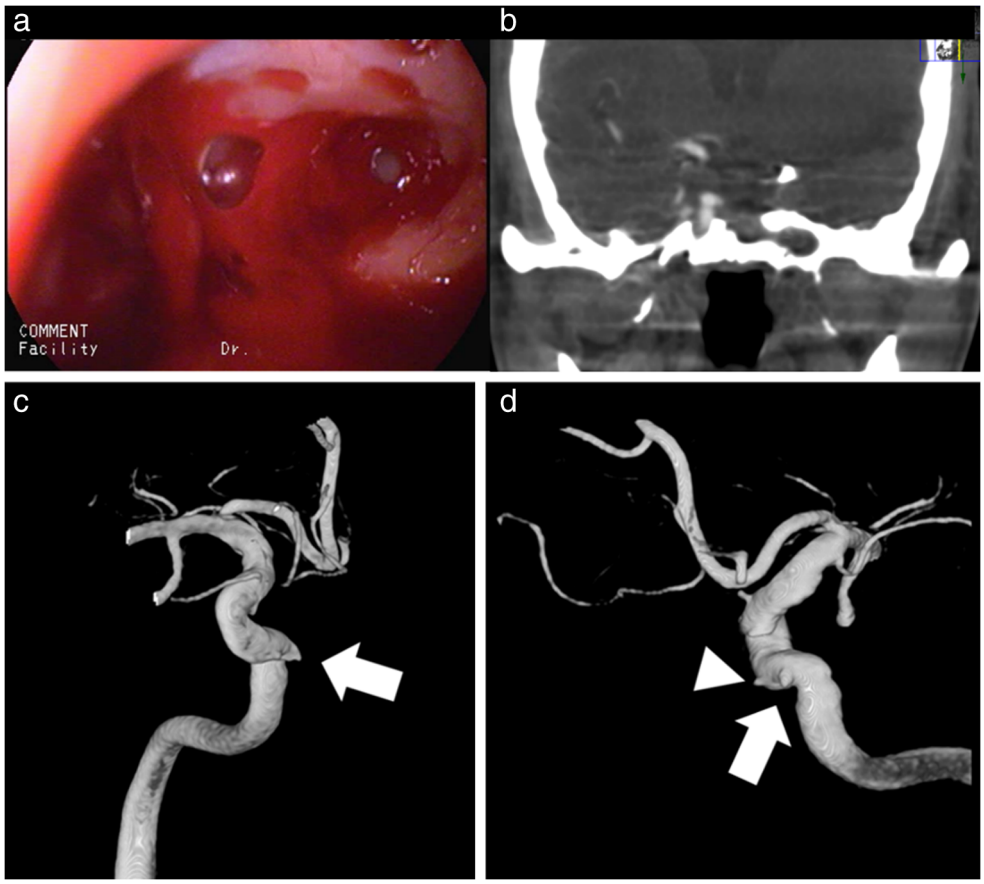

Fig. 3 **a** Endoscopic examination showing pulsatile bleeding in the sphenoid sinus, which had been opened at the time of transsphenoidal surgery. **b** Cone-beam computed tomography image showing the aneurysm in the sphenoid sinus. **c**, **d** Three-dimensional digital subtraction angiography showing two aneurysms (5 mm (arrow) and 2 mm (triangle)). The aneurysms were located in the cavernous portion

appeared to be the source of bleeding (Fig. 3b–d). The aneurysms were located on the cavernous portion of the right ICA in the irradiated area (Fig. 2b). We diagnosed the case as epistaxis due to the rupture of the radiation-associated aneurysms.

Because of their location and shape, the aneurysms were difficult to treat with ligation or clipping. Therefore, we performed superficial temporal artery to middle cerebral artery (STA-MCA) and external carotid artery to middle cerebral artery (ECA-MCA) bypass surgery, using a radial artery graft. Subsequently, endovascular surgery was performed to confirm complete haemostasis by the internal trapping of ICA aneurysms. The anterograde flow of the right ICA was interrupted. The flow of the bypass covered the right cerebral hemisphere, and flowed out to the ophthalmic artery (Fig. 4a, b). The patient did not develop any new focal neurological deficit, and the bleeding ceased. He was discharged with a modified Rankin Scale score of 1.

Discussion

In all cases of radiation-associated aneurysms reported to date, the aneurysms appeared from a segment of the artery rather than from a branching site as in ordinary saccular aneurysms [4]. In a single-centre study, the incidence of delayed development of intracranial aneurysms following GKS for trigeminal neuralgia was high, at 0.90% (2 of 222 consecutive cases) [19]. Akamatsu et al. suggested that aneurysm formation was due to both radiation-associated vasculopathy and hemodynamic stress [2].

The clinical information of patients with post-SRS aneurysm formation is presented in the supplementary table. All these aneurysms were located in the irradiation area. The average time-to-discovery of the aneurysm after SRS (post-course) was 10 years (median, range 8 months to 20 years). The original disease was vestibular schwannoma in eight cases and AVM in five cases, with no case reports of pituitary adenoma including GHoma. Furthermore, no case of intracranial ICA aneurysm formation after SRS has been reported. Multiple aneurysms were found in our case and that reported by Hughes et al. [9]. The rupture risk of SRS-induced aneurysms relative to that of spontaneously occurring aneurysms is unclear. However, of the 19 cases, a rupture occurred in 14 (73.7%). Therefore, we recommend that SRS-induced aneurysms be treated upon discovery, even if the sizes are small. Because SRS is frequently used for patients with non-malignant diseases who are expected to have long lifespans,

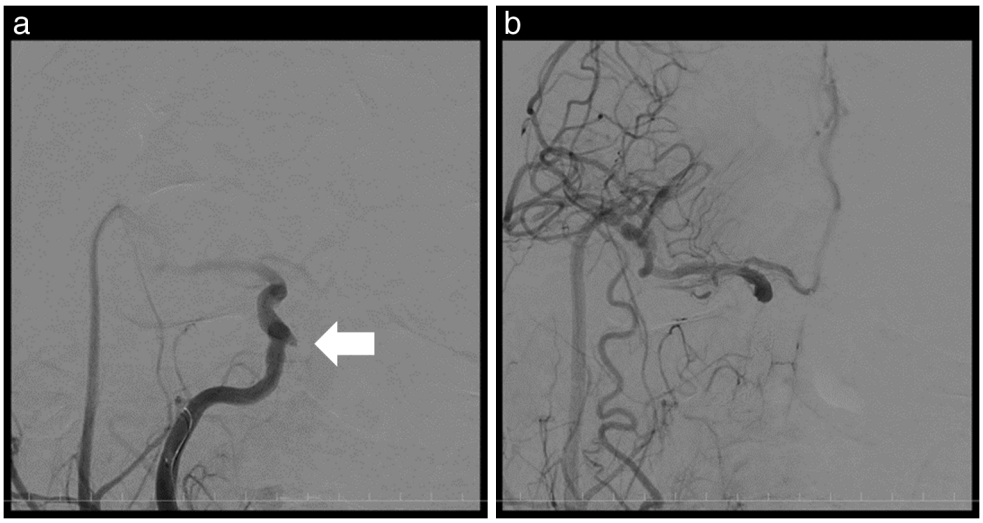

Fig. 4 **a** Angiogram performed before endovascular surgery. Before the treatment, we performed the superficial temporal artery to middle cerebral artery and external carotid artery to middle cerebral artery bypass surgery using a radial artery graft. **b** Angiogram after internal trapping of internal carotid artery aneurysms. The parent artery was occluded, and the aneurysms disappeared. The right cerebral hemisphere was perfused via a radial artery graft

a radiation-induced complication after SRS increases the amount of care required for such patients [1]. Different treatments were used in all reported cases of SRS-associated aneurysms. In cases where the flow of the parent artery needs to be protected, such as in our case, a parent artery occlusion after bypass surgery may be useful.

Mangiardi et al. have proposed four causes for pituitary adenomas coexisting with aneurysms: tumour infiltration of the vessel wall, increase in flow and tension of tumour vessels, effect of hormones, and vessel wall injury due to previous treatment [11]. Nishi et al. have also stated that an increased GH may influence systemic arteriosclerosis and aneurysm formation [15]. In the present case, the GHoma was well controlled for 20 years and the GH-levels before epistaxis were low because of anterior pituitary failures. Thus, the aneurysms may not have been caused by the tumour infiltration, increase in flow and tension of tumour vessels, and effect of hormones. The other causes were TSS, SRS, and natural occurrence. The tumour around the right ICA was difficult to access, and the likelihood that TSS caused any damage to the right ICA was low (Fig. 1). Furthermore, the MR image (T1 weighted with Gd) before TSS and SRS did not show the presence of aneurysms. Thus, the aneurysms may not have been caused by TSS. We cannot exclude the possibility that their formation and development were unrelated to any external factors or to any combination of the treatments, because we did not perform angiography before SRS and histological examination. In a study on the long-term effects of GKS in 30 acromegalic patients, no patient suffered from a ruptured aneurysm [3]. We believe, however, that the aneurysms in the present case might be SRS-associated for the following reasons. First, the aneurysms were located in the irradiated area. Second, the aneurysms appeared from a segment of the ICA rather than from a branching site, similar to all SRS-associated aneurysms reported to date.

Conclusion

Herein, we report the first case of aneurysms diagnosed following TSS and SRS for GHoma. The aneurysm developed many years after SRS; it may be necessary to consider the likelihood of the aneurysm formation after SRS, in the long-term prognosis of the patients. Considering that only 19 cases have been reported to date, further investigation of such cases is necessary to elucidate the pathophysiology of aneurysm formation after SRS.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflicts of interest.

Informed consent The patient has consented to the submission of this case report to the journal.

References

1. Akai T, Torigoe K, Fukushima M, Iizuka H, Hayashi Y (2015) De novo aneurysm formation following gamma knife surgery for arteriovenous malformation: a case report. J Neurol Surg Rep 76:e105–e108
2. Akamatsu Y, Sugawara T, Mikawa S, Saito A, Ono S, Takayama K, Jokura H, Seki H (2009) Ruptured pseudoaneurysm following gamma knife surgery for a vestibular schwannoma. J Neurosurg 110:543–546
3. Attanasio R, Epaminonda P, Motti E, Giugni E, Ventrella L, Cozzi R, Farabola M, Loli P, Beck-Peccoz P, Arosio M (2003) Gamma-knife radiosurgery in acromegaly: a 4-year follow-up study. J Clin Endocrinol Metab 88:3105–3112
4. Benson PJ, Sung JH (1989) Cerebral aneurysms following radiotherapy for medulloblastoma. J Neurosurg 70:545–550

5. Chen JC, Chao K, Rahimian J (2017) De novo superior cerebellar artery aneurysm following radiosurgery for trigeminal neuralgia. J Clin Neurosci 38:87–90
6. Gonzales-Portillo GA, Valdivia JM (2006) Uncommon presentation of pediatric ruptured intracranial aneurysm after radiotherapy for retinoblastoma. Case report. Surg Neurol 65:391–395 discussion 395-396
7. Gross BA, Ropper AE, Du R (2014) Vascular complications of stereotactic radiosurgery for arteriovenous malformations. Clin Neurol Neurosurg 115(6):713–717
8. Huang PP, Kamiryo T, Nelson PK (2001) De novo aneurysm formation after stereotactic radiosurgery of a residual arteriovenous malformation: case report. AJNR Am J Neuroradiol 22:1346–1348
9. Hughes JD, Osetinsky LM, Jacob JT, Carlson ML, Lanzino G, Link MJ (2015) Incidentally discovered unruptured AICA aneurysm after radiosurgery for vestibular schwannoma: a case report and review of the literature. Otol Neurotol 36:1428–1431
10. Kellner CP, McDowell MM, Connolly ES Jr, Sisti MB, Lavine SD (2014) Late onset aneurysm development following radiosurgical obliteration of a cerebellopontine angle meningioma. BMJ Case Rep 2014:bcr2014011206
11. Mangiardi JR, Aleksic SN, Lifshitz M, Pinto R, Budzilovic GN, Pearson J (1983) Coincidental pituitary adenoma and cerebral aneurysm with pathological findings. Surg Neurol 19:38–41
12. Mascitelli JR, McNeill IT, Mocco J, Berenstein A, DeMattia J, Fifi JT (2015) Ruptured distal AICA pseudoaneurysm presenting years after vestibular schwannoma resection and radiation. BMJ Case Rep 2015:bcr2015011736
13. Murakami M, Kawarabuki K, Inoue Y, Ohta T (2016) Ruptured pseudoaneurysm after gamma knife surgery for vestibular schwannoma. Neurol Med Chir (Tokyo) 56:38–42
14. Nanney AD 3rd, El Tecle NE, El Ahmadieh TY, Daou MR, Bit Ivan EN, Marymont MH, Batjer HH, Bendok BR (2014) Intracranial aneurysms in previously irradiated fields: literature review and case report. World Neurosurg 81:511–519
15. Nishi T, Matsukado Y, Kodama T, Hiraki T (1987) Multiple intracranial aneurysms following radiation therapy for pituitary adenoma. Case report. Neurol Med Chir (Tokyo) 27:224–228 [Article in Japanese]
16. Park KY, Ahn JY, Lee JW, Chang JH, Huh SK (2009) De novo intracranial aneurysm formation after gamma knife radiosurgery for vestibular schwannoma. J Neurosurg 110:540–542
17. Sunderland G, Hassan F, Bhatnagar P, Mitchell P, Jayakrishnan V, Forster D, Mendelow AD (2014) Development of anterior inferior cerebellar artery pseudoaneurysm after gamma knife surgery for vestibular schwannoma. A case report and review of the literature. Br J Neurosurg 28:536–538
18. Takao T, Fukuda M, Kawaguchi T, Nishino K, Ito Y, Tanaka R, Sato M (2006) Ruptured intracranial aneurysm following gamma knife surgery for acoustic neuroma. Acta Neurochir 148:1317–1318 discussion 1318
19. Uchikawa H, Nishi T, Kaku Y, Goto T, Kuratsu JI, Yano S (2017) Delayed development of aneurysms following gamma knife surgery for trigeminal neuralgia: report of 2 cases. World Neurosurg 99:813.e13–813.e19
20. Yamaguchi S, Kato T, Takeda M, Ikeda H, Kitamura K (2009) Ruptured distal anterior inferior cerebellar artery aneurysm following stereotactic irradiation for vestibular schwannoma: case report. Neurol Med Chir (Tokyo) 49:202–205

Publisher's note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Comments

It is important to recognise any possible late complications of any medical intervention, radiosurgery included.
However, I am far from convinced that a causative connection exists between the treatment and the ruptured aneurysm, and this presentation does not alter this view. Without an angiography done at the time of radiosurgery, one could not be certain about the presence or absence of the vascular anomaly back then. Furthermore, the tumour itself may be a sufficient explanation for the development of an aneurysm even if it was not present at the time of treatment.
The coexistence of pituitary tumours and aneurysms is well recognised. The two references from the late 1970s show angiography was still a common procedure. It was recognised that aneurysm formation was more common in the presence of a pituitary tumour than without or in the presence of another type of intracranial tumour. Various local causes were postulated. In the authors' case, even the pre-radiosurgery transsphenoidal surgery cannot be entirely ruled out as contributory. I realise that the treatment may well have affected the vessel; the effect cannot be entirely ruled out. I feel that it would be inappropriate to recommend late imaging for all patients in this category purely on the basis of this case report.

Andras Kemeny
Sheffield, UK

1. Jakubowski J, Kendall B. (1978) Coincidental aneurysms with tumours of pituitary origin. J Neurol Neurosurg Psychiatry. 1978 41(11):972-9.
2. Wakai S, Fukushima T, Furihata T, Sano K. (1979) Association of cerebral aneurysm with pituitary adenoma. Surg Neurol.12(6):503-7.