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ORIGINAL ARTICLE

# Efficacy of endovascular intervention in patients with unruptured posterior communicating artery aneurysm-related oculomotor nerve palsy

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## Abstract

**OBJECTIVES:** Oculomotor nerve palsy (ONP) is commonly encountered in daily neurosurgical activities. The ONP secondary to un-ruptured PComA aneurysm might be a unique entity that was different in diagnosis, treatment and prognosis from its ruptured counterparts. Perhaps as a result of the limitation in sample size, studies that solely focused on factors affecting recovery of ONP in patients with unruptured corresponding PComA aneurysms were scarce.

**METHODS:** In this study, we would like to report a relatively larger case series of patients with un-ruptured PComA aneurysm-related ONP. A retrospective review of medical records of 39 patients with un-ruptured PComA aneurysm-related ONP was performed with endovascular coiling.

**RESULTS:** All 39 consecutive patients underwent endovascular coiling. Eighteen (46%) patients had a complete resolution of ONP, 14 (36%) patients had a partial resolution. Time interval from onset of ONP to endovascular intervention ($P$=0.004), degree of ONP ($P$=0.015) and age (P=0.016) were predictors of ONP recovery with statistical significance. Sex, aneurysm size and risk factor exposure (smoking, alcohol abuse and hypertension) were not associated with ONP outcomes.

**CONCLUSION:** ONP secondary to un-ruptured aneurysm should be treated as a unique entity from its ruptured counterparts. A prospective study that contains surgical clipping and endovascular coiling, and comparison between two treatment modalities would be more convincing and is anticipated.

## INTRODUCTION

Oculomotor nerve palsy (ONP) is commonly encountered in daily neurosurgical activities (Amano *et al.* 2018; Zu *et al.* 2017; Hall *et al.* 2017). The concomitant existence of a posterior communicating artery (PComA) aneurysm should be considered in the differential diagnosis of ONP (Zu *et al.* 2017; Gao *et al.* 2017), because the incidence of ONP in patients with PComA aneurysms can be as high as 56% (Giombini *et al.* 1991; Kassis *et al.* 2010). The sudden onset of ONP may reflect the rapid growth of an unruptured aneurysm and should be considered a warning sign of an impending rupture Hu *et al.* 2015; Bederson *et al.* 2000). Although surgical clipping and endovascular coiling are treated as the two standard treatment modalities, many studies including systematic reviews support the viewpoint that endovascular coiling was superior Mino *et al.* 2015; Khan *et al.* 2013). Most of the published case series and reviews mainly focused on the difference in efficacy between the two treatment modalities or factors associated with ONP recovery. Perhaps as a result of the limitation in sample size, studies that solely focused on the factors affecting the recovery of ONP in patients with unruptured corresponding PComA aneurysms were scarce (Hu *et al.* 2015). So ONP secondary to ruptured or unruptured PComA aneurysms were always mixed together in these studies (Giombini *et al.* 1991; Kassis *et al.* 2010; Güresir *et al.* 2011; Brigui *et al.* 2014). In this study we would like to perform a retrospective review of the medical records of 39 patients with unruptured PComA aneurysm-related ONP. All of the 39 consecutive patients underwent endovascular coiling. To our knowledge, this is the largest cases series on this specific topic so far.

## EXPERIMENTAL

### *Study protocol*

A retrospective review of the medical records of patients admitted to our institution for ONP between January 2001 and March 2013 was made under the approval of institutional ethics committee. Among the 845 consecutive patients with ONP, 48 (5.7%) were identified with corresponding unruptured ipsilateral PComA aneurysms according to the set criteria, of whom 39 underwent endovascular coiling according to the International Study of Unruptured Intracranial Aneurysms criteria (Wiebers *et al.* 2003) and the willingness of the patients. All the surgeries were performed by 2 surgeons in the same medical team. Clinical data including sex, age, degree of ONP on admission, time interval from symptom onset to surgery, size, risk factors as smoking, alcohol abuse and hypertension and outcome were extracted from the data base (Table 1). The degree of ONP was assessed by one ophthalmologist on admission, while the degree of recovery was assessed by the same staff according to the follow-up questionnaires or inspection in outpatient clinic.

### *Diagnosis of unruptured PComA aneurysm-related ONP*

Unruptured PComA aneurysm was deemed as the corresponding cause of ONP when all of the criteria were met.

ONP as the sole complaint on admission. Radiological examination after the onset of ONP revealed no subarachnoid hemorrhage. Ipsilateral PComA aneurysm was identified on CT angiography (CTA) or digital substraction angiography (DSA). No other risk factor that might contribute to ONP could be identified.

### *Definition of the degree of ONP on admission and recovery outcome*

Patients presenting with all of the symptoms above were deemed as with complete ONP, while those presenting with one or two or incomplete presentation of the symptoms were deemed as with incomplete ONP. Complete resolution was defined as complete recovery of the symptoms above. Partial resolution was defined as one or more of the symptoms partially recovered.

### *Surgical procedure*

Endovascular treatment was performed under general anesthesia with systemic heparinization on a biplane angiographic unit (Philips Integra V3000 Neuro; Philips Medical Systems, Best, the Netherlands). Heparinization was continued for 48 hours after treatment, followed by 80 mg aspirin daily for 3 months. Aneurysm occlusion was performed with Guglielmi detachable coils (Boston Scientific, Fremont, Calif), and one giant PCA aneurysm was occluded with very long mechanically detachable coils (Detach 18; Cook, Copenhagen, Denmark). Aneurysms with a well-defined neck were selectively occluded with coils and aneurysms without a defined neck were occluded together with the parent PCA.

### *Statistical analysis*

Six independent variables according to the literature and our medical records were obtained. They were sex, age, degree of ONP, time interval from ONP onset to surgery, risk factor exposure and aneurysm size. Continuous variables as age, symptom interval and aneurysm size were expressed as mean ± SD and assessed with a two-tailed student t-test. Categorical variables were assessed by chi-squared or Fisher exact test. SPSS 17.0 was used in the statistical analysis and $p<0.05$ was considered with statistical significance.

## RESULTS

This study consisted of 39 (15 males) patients and 32 patients (82%) enjoyed ONP recovery in different degrees. Eighteen (46%) patients had a complete resolution of ONP, 14 (36%) patients had a partial resolution. The time interval from onset of ONP to endovascular coiling ranged from one day to one year. Clinical

**Tab. 1.** Clinical and demographic data of the patients

| Patient | Sex | Age | Risk factor | State on admission | Size | Interval | Outcome | Follow-up |
|---|---|---|---|---|---|---|---|---|
| 1 | M | 45 | P | PP | 8mm | 8d | CR | 12m |
| 2 | F | 42 | N | CP | 5mm | 31d | PR | 9m |
| 3 | F | 52 | P | PP | 10mm | 22d | CR | 15m |
| 4 | F | 65 | P | CP | 9mm | 45d | NR | 28m |
| 5 | M | 32 | N | CP | 13mm | 3d | PR | 24m |
| 6 | M | 47 | N | CP | 11mm | 17d | PR | 32m |
| 7 | F | 38 | N | PP | 10mm | 4d | CR | 6m |
| 8 | F | 71 | P | CP | 8mm | 49d | NR | 40m |
| 9 | F | 64 | P | CP | 12mm | 27d | PR | 40m |
| 10 | M | 51 | P | CP | 8mm | 1y | NR | 40m |
| 11 | F | 28 | N | PP | 14mm | 2d | CR | 6m |
| 12 | M | 74 | N | PP | 12mm | 15d | CR | 20m |
| 13 | F | 47 | N | PP | 5mm | 4d | CR | 8m |
| 14 | M | 55 | P | CP | 8mm | 3d | PR | 24m |
| 15 | F | 21 | N | PP | 16mm | 1d | PR | 24m |
| 16 | F | 73 | N | CP | 9mm | 10d | PR | 24m |
| 17 | M | 60 | P | CP | 6mm | 4d | PR | 19m |
| 18 | F | 42 | P | PP | 9mm | 7d | CR | 12m |
| 19 | F | 32 | N | CP | 12mm | 2d | PR | 24m |
| 20 | M | 54 | N | CP | 14mm | 29d | NR | 24m |
| 21 | M | 47 | N | CP | 13mm | 3d | CR | 15m |
| 22 | F | 54 | N | PP | 7mm | 9d | CR | 20m |
| 23 | F | 35 | N | CP | 10mm | 15d | PR | 24m |
| 24 | M | 54 | P | PP | 7mm | 8d | CR | 12m |
| 25 | F | 60 | P | PP | 11mm | 9d | PR | 24m |
| 26 | F | 35 | N | PP | 7mm | 3d | CR | 12m |
| 27 | F | 45 | P | CP | 7mm | 48d | NR | 24m |
| 28 | F | 55 | P | PP | 10mm | 5d | CR | 12m |
| 29 | M | 48 | P | CP | 5mm | 7d | CR | 12m |
| 30 | M | 53 | P | PP | 8mm | 9d | CR | 14m |
| 31 | F | 73 | N | CP | 12mm | 35d | NR | 24m |
| 32 | F | 35 | P | PP | 8mm | 3d | CR | 12m |
| 33 | F | 56 | N | CP | 7mm | 14d | NR | 24m |
| 34 | F | 43 | N | PP | 8mm | 10d | CR | 12m |
| 35 | M | 46 | P | CP | 11mm | 18d | PR | 27m |
| 36 | M | 56 | P | PP | 5mm | 21d | PR | 24m |
| 37 | F | 44 | N | PP | 7mm | 5d | CR | 12m |
| 38 | M | 34 | N | CP | 6mm | 4d | CR | 12m |
| 39 | F | 43 | N | PP | 11mm | 3d | PR | 24m |

F: Female, M: Male, P: Positive, N: Negative, CP: Complete palsy, PP: Partial palsy, CR: Complete resolution, PR: Partial resolution, NR: Non-resolution

follow-up ranged from 6 to 40 months. The outcome was assessed as ONP resolution (partial or complete) or non-resolution. The details of statistical analysis are summarized in Table 2 and the relationship between the demographic and clinical data and ONP recovery would be illustrated separately.

*Gender and age*

The overall efficacy of endovascular coiling in male and female was 87% and 79%, respectively. No statistical significance (*P*=0.869) was noted (Table 2). Patients with no resolution of ONP (59.29 ± 10.56 year) were older than those with resolution (46.69 ± 12.26 year) with statistical significance (Table 2, *P*=0.016).

*Exposure to risk factors*

We treated smoking, alcohol abuse and hypertension as the risk factors. Because diabetes has long been demonstrated to be an independent cause of ONP by some studies, it was excluded from our risk factor family. If one or more of the three risk factors were present, the patient would be treated as risk factor exposure positive, negative otherwise. Seventy-six percent of patients with risk exposure and 86% patients without enjoyed ONP resolution (complete or partial). Statistical significance was not reached (Table 2, *P*=0.706).

*Degree of ONP on admission*

ONP recovered in 19 (95%) of 20 patients with partial ONP and in 13 (68%) of 19 patients with complete ONP and the difference was statistically significant (Table 2, *P*=0.015).

*Time interval from ONP onset to endovascular coiling*

Patient 10 had suffered from ONP for one year before admission and he experienced no remission of the symptom during a follow-up of 40 months. As his symptom of ONP was extremely longer compared with his counterparts', he was excluded from the statistical analysis of the relationship between time interval from ONP onset to endovascular coiling and ONP recovery. The time interval in the patients with resolution (9.13 ± 7.74 day) was significantly shorter than those without (36.67 ± 13.60 day) (Table 2, *P*=0.004).

*Size of the aneurysm*

Aneurysm sizes were 9.19 ± 2.87 mm and 9.29 ± 2.69 mm in patients with resolution and without, respectively. No statistical significance (Table 2, *P*=0.934) was noted.

## DISCUSSION

The incidence of ONP in patients with PComA aneurysms can be as high as 56%[5, 6]. A sudden onset of ONP may reflect the rapid growth of an unruptured aneurysm and should be considered a warning sign of an impending rupture (Hu *et al.* 2015; Bederson *et al.* 2000). Historically, surgical clipping was considered as standard or even sole treatment modality for ONP recovery and prevention of aneurysm rupture, until the publication of Birchall's report of three patients successfully embolized in 1999 (Birchall *et al.* 1999). Although some authors have enthusiastically demonstrated the successful application of endovascular coiling in a relatively larger population (Santillan *et al.* 2010; Ko & Kim 2011; Chalouhi *et al.* 2013), up to date studies including some meta-analyses still supported the superiority of surgical clipping vs endovascular coiling (Güresir *et al.* 2011; Tan *et al.* 2015; Brigui *et al.* 2014; Chen *et al.* 2006).

The difference between two the treatment modalities in efficacy on ONP recovery might be partly due to the mechanism of ONP. Generally speaking, a combination of the compressive mass effect of the aneurysm and irritation caused by its pulsation is the preferred pathophys-

**Tab. 2.** Relationships between variables and ONP recovery.

| Clinical data | | Outcome | | | P value |
|---|---|---|---|---|---|
| | | Resolved | | | |
| | | CR (N, %) | PR (N, %) | NR (N, %) | |
| Sex | Male | 7, 47% | 6, 40% | 2, 13% | 0.869 |
| | Female | 11, 46% | 8, 33% | 5, 21% | |
| Risk factor | P | 7, 41% | 6, 35% | 4, 24% | 0.706 |
| | N | 11, 50% | 8, 36% | 3, 14% | |
| Degree of ONP | CP | 3, 16% | 10, 53% | 6, 31% | 0.015 |
| | PP | 15, 75% | 4, 20% | 1, 5% | |
| Age (y, mean ± SD) | | 46.69 ± 12.26 | | 59.29 ± 10.56 | 0.016 |
| Interval (d, mean ± SD) | | 9.13 ± 7.74 | | 36.67 ± 13.60 | 0.004 |
| Size (mm, mean ± SD) | | 9.19 ± 2.87 | | 9.29 ± 2.69 | 0.934 |

P: Positive, N: Negative, CR: Complete resolution, PR: Partial resolution, NR: Non-resolution

iological mechanism of ONP in the setting of PComA aneurysm (Güresir *et al.* 2011). It is believed that coiling relieves irritation caused by aneurysm pulsatility, while surgery resolves both pulsatility and the mass effect (Brigui *et al.* 2014; Chen *et al.* 2006). Furthermore, the coil mass itself could contribute to mass effect. In the present study, all the 39 consecutive patients underwent endovascular coiling, intraoperative decompression was also applied if needed. But as our study showed, the rates of complete resolution and partial resolution were 46% and 36%, respectively. No superiority in efficacy was observed compared with the previous studies on surgical clipping vs endovascular coiling (Kassis *et al.* 2010; Güresir *et al.* 2011; Chen *et al.* 2006; Nam *et al.* 2010). However, this study solely focused on unruptured aneurysms with endovascular coiling, which might have perplexed the interpretation of results.

Most of the published case series and reviews on PComA aneurysm-related ONP mainly focused on the difference in efficacy between the two treatment modalities or factors affecting ONP recovery (Kassis *et al.* 2010; Güresir *et al.* 2011; Chalouhi *et al.* 2013; Gu *et al.* 2012). But ONP secondary to unruptured PComA aneurysm might be a unique entity that was different in diagnosis, treatment and prognosis from its ruptured counterparts. A prospective study that contains ruptured and unruptured aneurysms, surgical clipping and endovascular coiling and statistical analysis of the two treatment modalities in different circumstances is more convincing. A relative large case series of unruptured PComA aneurysm-related ONP before this study was described by Yanaka K and colleagues in 2003[22]. This study consisted of 16 patients with ONP (13 due to PComA aneurysm). Among the 13 patients, one died from aneurysm rupture before endovascular coiling was performed, one underwent endovascular coiling with no change to ONP, the remained 11 underwent endovascular coiling with 10 (91%) enjoyed ONP recovery (4 incomplete, 6 complete).

According to the past studies and our medical records, we chose 6 independent variables (sex, age, exposure to risk factors, time interval from ONP onset to endovascular coiling, degree of ONP on admission and aneurysm size) for statistical analysis. Consistent with the past studies (Giombini *et al.* 1991; Hu *et al.* 2015; Güresir *et al.* 2011), timely endovascular coiling was still the most potent factor affecting ONP recovery ($P$=0.004). Sex ($P$=0.869) and exposure to risk factors (smoking, alcohol abuse and hypertension) ($P$=0.706) were not indicative of ONP resolution. Contrary to our common intuitive but consistent with the previous studies (Hu *et al.* 2015; Güresir *et al.* 2011; Tan et al 2015; Chen *et al.* 2006), aneurysm size was not related to nerve function recovery ($P$=0.934). This might be explained by a recently published article which concluded that a shorter distance between internal carotid artery (ICA) and anterior-posterior clinoid process may be related to the occurrence of PCoA aneurysm-related ONP (Anan *et al.* 2014). Even relatively small unruptured PCoA aneurysms can cause third nerve palsy if the ICA runs adequately close to the skull base, this means that the PCoA aneurysm should be closer to the third nerve when the ICA runs closer to the skull base (Anan *et al.* 2014). Degree of ONP on admission was another factor accounting for the prognosis of recovery. This study indicated that patients with partial ONP (95%) was more likely to have a better oculomotor nerve recovery than those with complete palsy (68%) ($P$=0.015). But the relationship between degree of ONP and recovery varied according to different reports (Kassis *et al.* 2010; Hu *et al.* 2015; Chen *et al.* 2006; Nam *et al.* 2010). In previous reports age was not associated with ONP recovery (Kassis *et al.* 2010; Hu *et al.* 2015; Güresir *et al.* 2011; Chen *et al.* 2006; Nam *et al.* 2010). But contrary to previous reports, our study showed that younger patients enjoyed a better recovery then the older ($P$=0.016). This might be explained by the cultural and economical circumstance in China. As China is a developing country, the economic reality makes people pay less attention to seemingly nonfatal health problems, especially in the older people.

There are some deficiencies in our study. First of all, the sample size of this study is relatively small, and the promotion of the research results requires the verification of a larger sample. Secondly, due to the improvement of living standards, the rapid development of interventional materials, and the increasing maturity of intravascular treatment technologies, endovascular treatment of OMNPs caused by unruptured PComA is more effective, faster to restore the function of oculomotor nerve, and ultimately to improve the patient life quality.

## CONCLUSIONS

This study indicates that endovascular coiling could achieve encouraging neural recovery in patients with unruptured PComA aneurysm-related ONP. Time interval from onset of ONP to endovascular intervention is a potent predictor of ONP resolution. Degree of ONP on admission and age also affect outcome with statistical significance. Sex, aneurysm size, exposure of risk factors as smoking, alcohol abuse and hypertension are not associated with ONP recovery. ONP secondary to unruptured aneurysm should be treated as a unique entity from its ruptured counterparts. But this study has its own shortcomings. Firstly, it is retrospective in its nature. And then it only focuses on the efficacy of endovascular intervention. A prospective study that contains endovascular coiling and surgical clipping, and comparison between the two treatment modalities would be more convincing and is anticipated.

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REFERENCES

1 Amano E, Komatuzaki T, Ishido H, Ishihara T, Otsu S, Yamada I, et al. (2018) Pitfalls in the diagnosis of pupil-sparing oculomotor nerve palsy without limb ataxia: A case report of a variant of Claude's syndrome and neuroanatomical analysis using diffusion-tensor imaging. J Clin Neurosci. **47**: 120-123.
2 Anan M, Nagai Y, Fudaba H, Kubo T, Ishii K, Murata K, et al. (2014) Third nerve palsy caused by compression of the posterior communicating artery aneurysm does not depend on the size of the aneurysm, but on the distance between the ICA and the anterior-posterior clinoid process. Clin Neurol Neurosurg. **123**: 169-173.
3 Bederson JB, Awad IA, Wiebers DO, Piepgras D, Haley EC Jr, Brott T, et al. (2000) Recommendations for the management of patients with unruptured intracranial aneurysms: A statement for healthcare professionals from the Stroke Council of the American Heart Association. Circulation. **102**: 2300-2308.
4 Birchall D, Khangure MS, McAuliffe W. (1999) Resolution of third nerve paresis after endovascular management of aneurysms of the posterior communicating artery. AJNR Am J Neuroradiol. **20**: 411-413.
5 Brigui M, Chauvet D, Clarençon F, Degos V, Sourour NA, Nouet A, et al. (2014) Recovery from oculomotor nerve palsy due to posterior communicating artery aneurysms: results after clipping versus coiling in a single-center series. Acta Neurochir (Wien). **156**: 879-884.
6 Chalouhi N, Theofanis T, Jabbour P, Dumont AS, Gonzalez LF, Starke RM, et al. (2013) Endovascular treatment of posterior communicating artery aneurysms with oculomotor nerve palsy: clinical outcomes and predictors of nerve recovery. AJNR Am J Neuroradiol. **34**: 828-832.
7 Chen PR, Amin-Hanjani S, Albuquerque FC, McDougall C, Zabramski JM, Spetzler RF. (2006) Outcome of oculomotor nerve palsy from posterior communicating artery aneurysms: comparison of clipping and coiling. Neurosurgery. **58**: 1040-1046.
8 Gao G, Gu DQ, Zhang Y, Yu J, Chen Y, Chao YJ, et al. (2017) Comparison of the efficacy of surgical clipping and embolization for oculomotor nerve palsy due to a posterior communicating artery aneurysm. Eur Rev Med Pharmacol Sci. **21**: 292-296.
9 Giombini S, Ferraresi S, Pluchino F. (1991) Reversal of oculomotor disorders after intracranial aneurysm surgery. Acta Neurochir (Wien). **112**(1-2): 19-24.
10 Gu DQ, Luo B, Zhang X, Long XA, Duan CZ. (2012) Recovery of posterior communicating artery aneurysm-induced oculomotor nerve paresis after endovascular treatment. Clin Neurol Neurosurg. **114**: 1238-1242.
11 Güresir E, Schuss P, Setzer M, Platz J, Seifert V, Vatter H. (2011) Posterior communicating artery aneurysm-related oculomotor nerve palsy: influence of surgical and endovascular treatment on recovery: single-center series and systematic review. Neurosurgery. **68**: 1527-1533; discussion 1533-1534.
12 Hall S, Sadek AR, Dando A, Grose A, Dimitrov BD, Millar J, et al. (2017) The Resolution of Oculomotor Nerve Palsy Caused by Unruptured Posterior Communicating Artery Aneurysms: A Cohort Study and Narrative Review. World Neurosurg. **107**: 581-587.
13 Hu P, Qian Y, Lee CJ, Zhang HQ, Ling F. (2015) The energy loss may predict rupture risks of anterior communicating aneurysms: a preliminary result. Int J Clin Exp Med. **8**: 4128-4133.
14 Kassis SZ, Jouanneau E, Tahon FB, Salkine F, Perrin G, Turjman F. (2010) Recovery of third nerve palsy after endovascular treatment of posterior communicating artery aneurysms. World Neurosurg. **73**: 11-16; discussion e2.
15 Khan SA, Agrawal A, Hailey CE, Smith TP, Gokhale S, Alexander MJ, et al. (2013) Effect of surgical clipping versus endovascular coiling on recovery from oculomotor nerve palsy in patients with posterior communicating artery aneurysms: A retrospective comparative study and meta-analysis. Asian J Neurosurg. **8**: 117-124.
16 Ko JH, Kim YJ. (2011) Oculomotor nerve palsy caused by posterior communicating artery aneurysm: evaluation of symptoms after endovascular treatment. Interv Neuroradiol. **17**: 415-419.
17 Mino M, Yoshida M, Morita T, Tominaga T. (2015) Outcomes of Oculomotor Nerve Palsy Caused by Internal Carotid Artery Aneurysm: Comparison between Microsurgical Clipping and Endovascular Coiling. Neurol Med Chir (Tokyo). **55**: 885-890.
18 Nam KH, Choi CH, Lee JI, Ko JG, Lee TH, Lee SW. (2010) Unruptured Intracranial Aneurysms with Oculomotor Nerve Palsy: Clinical Outcome between Surgical Clipping and Coil Embolization. J Korean Neurosurg Soc. **48**: 109-114.
19 Santillan A, Zink WE, Knopman J, Riina HA, Gobin YP. (2010) Early endovascular management of oculomotor nerve palsy associated with posterior communicating artery aneurysms. Interv Neuroradiol. **16**: 17-21.
20 Tan H, Huang G, Zhang T, Liu J, Li Z, Wang Z. (2015) A retrospective comparison of the influence of surgical clipping and endovascular embolization on recovery of oculomotor nerve palsy in patients with posterior communicating artery aneurysms. Neurosurgery. **76**: 687-694.
21 Wiebers DO, Whisnant JP, Huston J, Meissner I, Brown RD Jr, Piepgras DG, et al. (2003) Unruptured intracranial aneurysms: natural history, clinical outcome, and risks of surgical and endovascular treatment. Lancet. **362**: 103-110.
22 Yanaka K, Matsumaru Y, Mashiko R, Hyodo A, Sugimoto K, Nose T. (2003) Small unruptured cerebral aneurysms presenting with oculomotor nerve palsy. Neurosurgery. **52**: 553-557.
23 Zu QQ, Liu XL, Wang B, Zhou CG, Xia JG, Zhao LB, et al. (2017) Recovery of oculomotor nerve palsy after endovascular treatment of ruptured posterior communicating artery aneurysm. Neuroradiology. **59**: 1165-1170.