Original Article

Endovascular treatment of unruptured posterior circulation intracranial aneurysms

Xianli Lv, Huijian Ge, Hengwei Jin, Hongwei He, Chuhan Jiang, Youxiang Li

Department of Interventional Neuroradiology, Beijing Neurosurgical Institute and Beijing Tiantan Hospital, Capital Medical University, Beijing, China

Abstract

Background and Purpose: Endovascular treatment of unruptured posterior circulation intracranial aneurysms (UPCIAs) is limited in the International Study of Unruptured Intracranial Aneurysms (ISUIA). The aim of this study is to evaluate the periprocedural morbidity, mortality, and midterm clinical and angiographic follow-ups of endovascular treatment of UPCIAs. **Materials and Methods:** Retrospective analysis of all patients treated in a 2-year period (89 patients: 10–78 years of age, mean: 45.5 ± 14.3/92 UPCIAs). Fifty-eight aneurysms were found incidentally, 12 in association with mass effect symptoms and 22 with stroke. **Results:** A clinical improvement or stable outcome was achieved in 84 patients (94.4%). The two cases of permanent morbidity included a patient with paralysis and another patient with hemianopia. One patient died after treatment of a giant fusiform vertebrobasilar aneurysm. In one patient, the aneurysm ruptured during treatment, resulting in death. Another patient suffered a fatal aneurysm rupture 4 days after treatment. Giant size ($P = 0.005$) and mass effect presentation ($P = 0.029$) were independent predictors of unfavorable outcomes in UPCIAs. Angiographic follow-up was available in 76 of the 86 surviving patients (88.4%) with a mean of 6.8 months (range: 1–36 months). Recanalization in six patients (7.9%) at 3 months, 4 months, 4 months, 24 months, and 36 months required retreatment in three patients. In-stent stenosis of >50% was found in three patients. **Conclusion:** Endovascular therapy is an attractive option for UPCIAs with stable midterm outcome. However, the current endovascular option seems to have a limitation for the treatment of the aneurysm with giant size or mass effect presentation.

Key Words

Endovascular treatment, intracranial aneurysm, outcome, posterior circulation, unruptured

For correspondence:
Dr. Chuhan Jiang and Youxiang Li, Beijing Neurosurgical Institute,
No. 6, Tiantan Xili, Chongwen, Beijing - 100 050, China.
E-mail: jiangchuhan126@126.com
E-mail: vxianli000@163.com

Ann Indian Acad Neurol 2016;19:302-306

Introduction

The perception that endovascular therapy is superior to microsurgical clipping for posterior circulation aneurysms is not based on clear evidence. Because very little data concerning the endovascular treatment of unruptured posterior circulation intracranial aneurysms (UPCIAs) are available to date,[1-7] our study evaluated the results obtained in a large series over a 4-year period at a single center.

Access this article online	
Quick Response Code:	Website: www.annalsofian.org
	DOI: 10.4103/0972-2327.186784

Materials and Methods

Subjects and methods

A retrospective analysis was undertaken for all patients with UPCIAs who received endovascular treatment in our department

How to cite this article: Lv X, Ge H, Jin H, He H, Jiang C, Li Y. Endovascular treatment of unruptured posterior circulation intracranial aneurysms. Ann Indian Acad Neurol 2016;19:302-6.
Received: 10-12-15, **Revised:** 17-01-16, **Accepted:** 29-01-16

between October 2009 and October 2011. A retrospective analysis and review were undertaken of the hospital and outpatient charts, the operative report, and all angiographic, computed tomography (CT), and magnetic resonance (MR) studies. This was supplemented by follow-up clinical examination and telephone interviews. Altogether, 92 unruptured cerebral aneurysms in 89 patients were treated. There was a clear male predominance: 75.3% men versus 24.7% women. The patients' ages ranged 10–78 years with an average age of 45.5 ± 14.3 years [Table 1]. Clinical presentation was as follows: 63.0% of the aneurysms were detected incidentally during neuroradiological imaging because of an unrelated medical condition such as headache (44.8%), dizziness (15.5%), unexplained diplopia (1.7%), 1.7% were identified after the patient had suffered an subarachnoid hemorrhage (SAH) from another aneurysm—these patients were electively treated after full recovery from the hemorrhage and 36.2% were asymptomatic, 13.0% became symptomatic because of the mass effect of the aneurysm, and 22.8% were found in addition to brain stem ischemia.

All patients' data—hospital files, operative reports, and outpatient charts collected during clinical routine by members of the department—were evaluated to screen for procedure-related morbidity and mortality. This information was supplemented by follow-up clinical examinations and telephone interviews to detect possible aneurysm rupture after treatment. This was done by one of the authors of the study. To calculate the overall procedural complication rate, all interventions regarding the endovascular treatment were evaluated: initial endovascular treatment, subsequent endovascular retreatments, and angiographic follow-up. The complication rate was calculated per treated aneurysm.

The diagnostic, postprocedural, and follow-up angiograms were reviewed by one of the authors to obtain the degree of aneurysm occlusion. Immediate postprocedure angiography measured aneurysm occlusion using a modification of the Raymond classification scale, which was primarily developed for berry-shaped aneurysms.[8]

Aneurysm dimensions and locations were determined [Tables 1 and 2]. The size of the treated aneurysms ranged 3–35 mm with a mean diameter of 12.7 ± 7.5 mm. Aneurysm size was classified into the same four groups as per the International Study of Unruptured Intracranial Aneurysms (ISUIA) 2003;[9] aneurysm of the neck was considered narrow if < 4 mm and wide if ≥ 4 mm. Aneurysm dimensions were measured with the angiography equipment, and the size was estimated through comparison with the diameter of the parent vessel and the coil size used. In addition, the size was evaluated by CT angiography or MR tomography. Among the treated aneurysms, three (3.2%) were saccular in shape and had a narrow neck (<4 mm), 9 (9.8%) were saccular and harbored a wide neck (>4 mm), and 80 (87.0%) were fusiform. For statistical analysis, a general linear model was used; $P < 0.05$ was considered to be significant. Statistical calculations were performed using Statistical Package for the Social Sciences (SPSS) 16.0 (SPSS Institute Inc.).

Indications for aneurysm treatment

Patients with UPCIAs were normally referred to the outpatient clinic of our neurovascular service after detection of the aneurysm at another institution. There, the treatment options for every individual patient were carefully assessed and endovascular therapy became the first choice treatment.

Table 1: Patient demographic and aneurysm dimensions

Patient's age		
Mean	45.5±14.3	
Min	10	
Max	78	
Age distribution		
<40 years	23	(25.8%)
40-69 years	62	(69.7%)
≥70 years	4	(4.5%)
Sex		
Men	67	(75.3%)
Women	22	(24.7%)
Aneurysm size		
Mean	12.7±7.5	
Min	3 mm	
Max	36 mm	
Small (<7 mm)	20	(21.7%)
Medium (7-12 mm)	33	(35.9%)
Large (13-24 mm)	28	(30.4%)
Giant (≥25 mm)	11	(12.0%)
Neck (<4 mm)	3	(3.3%)
Neck (≥4 mm)	89	(96.7%)

Table 2: Aneurysm location

PCA	P1	1	(1.1%)
	P2	14	(15.2%)
	P3	1	(1.1%)
BA	BA bifurcation	4	(4.3%)
	BA/SCA	4	(4.3%)
BA-AICA		3	(3.3%)
VBJ		13	(14.1%)
PICA		1	(1.1%)
VA-PICA		51	(55.4%)

VA = Vertebral artery, PICA = Posterior inferior cerebellar artery, VBJ = Vertebrobasilar junction, BA = Basilar artery, SCA = Superior cerebellar artery, PCA = Posterior cerebral artery

Endovascular technique

All of cases used relied on general anesthesia by a dedicated neuroanesthesiology team with neuromuscular blockade to prevent patient motion and improve control over patient hemodynamics in case of an adverse event such as aneurysm perforation. A 6F vascular access sheath was inserted in the common femoral artery. Complete diagnostic angiography was performed through a 5F catheter with the use of high-resolution digital subtraction angiography to evaluate the presence and extent of vasospasm and other intracranial vascular anomalies. When the patients received endovascular treatment, one of three types of endovascular treatment, simple coiling for aneurysms with a small neck, deconstructive or reconstructive for wide-necked aneurysms was given [Table 3]. Deconstructive treatments sacrifice the parent artery, and include proximal occlusion or internal coil trapping of the parent artery. Reconstructive treatments preserve the parent artery patency using one

Table 3: Treatment for 92 UPCIAs

Treatment	No. of UPCIAs	Locations of UPCIAs		
		PCA	BA	VA-PICA
Simply coiling	3	0	2	1
Stent-assisted coiling	46	1	15	30
Parent vessel occlusion	34	15	3	16
Stenting alone	9	0	4	5
Total	92	16	24	52

to two overlapping stents, with or without coiling. The treatment type was determined on a case-by-case basis at each interventional neuroradiologist's discretion according to the presenting symptoms, hemodynamic status, lesion type, and anatomic factors of the vertebrobasilar artery. Self-expanding neurovascular stents (Neuroform, Boston Scientific; Leo, Balt; Enterprise, Codman; Solitaire, ev3; Silk, Balt) have been preferably used. Patients with stenting received 100 mg of aspirin and 75 mg of clopidogrel for 3–5 days before treatment and received dual antiplatelet medication (100 mg of aspirin and 75 mg of clopidogrel) after the procedure. Dual antiplatelet medication was maintained for 4 weeks and then was changed to aspirin monotherapy for 6 months.

Statistical analysis

The overall risk of morbidity or mortality was estimated as the proportion of patients who were disabled or dead at 30 days and at 1 year. Procedure-related morbidity and mortality were estimated on the basis of those events attributed to treatment of the aneurysm. Factors related to overall morbidity and mortality were determined with the use of logistic regression.

Angiographic follow-up

Follow-up angiography was scheduled 3–6 months after embolization. If a stable result was demonstrated, another angiography was advised 2–3 years after embolization. If the angiography showed recanalization, follow-up angiographies were performed at 3–6-month intervals. In the event of a significant remnant or aneurysm growth, the patient was advised to undergo additional endovascular therapy.

Results

Immediate results

On immediate angiogram, 57 of 92 (62.0%) aneurysms were occluded without remnant (2 simply coiling, 22 stent-assisted coiling, and 33 parent vessel occlusions). Of the 26 aneurysms (28.3%) with subtotal occlusion after treatment (1 simply coiling, 24 stent-assisted coiling, and 1 parent vessel occlusion), 11 had filling of a residual base (Raymond Class 2), whereas the other 15 had residual dome filling (Raymond Class 3). Contrast residual time within the aneurysm was increased moderately after the stent placement in the nine patients treated by stenting alone.

Excellent technical and clinical results were achieved in 84 of 89 patients (94.4%) without any complication. Clinical adverse events occurred in five patients leading to two cases of major permanent morbidity (2.2%) and three cases of death (3.4%). Giant size ($P = 0.005$) and mass effect presentation ($P = 0.029$) were independent predictors of unfavorable outcomes in UPCIAs. Patient age, sex, aneurismal location, and treatment modality were not significant.

The two cases of major permanent morbidity both involved infarctions. A patient sustained a hemianopia after parent vessel occlusion of a posterior cerebral artery. After placement of one stent into the basilar trunk, one patient had a minor stroke as documented by magnetic resonance imaging (MRI) associated with a small pontine perforator occlusion and retained permanent left limbs' weakness and hypoesthesia. One patient died 5 days after treatment. The initial attempted endovascular treatment was successful with SILK flow diverter placed from the vertebral artery to the basilar artery for the 30-mm giant and saccular symptomatic vertebrobasilar junction aneurysms. CT scanning suggested that the death was a result of hemorrhage of the aneurysm (not shown). A 77-year-old man presented with headache, hemi-hypoesthesia, dysarthria, and gait instability caused by a giant saccular aneurysm of the intradural vertebral artery. The aneurysm was treated with Neuroform stent-assisted coiling. After embolization, the patient did not wake up from general anesthesia and CT scanning showed a severe subarachnoid hemorrhage. He deteriorated rapidly and died 3 h later. We postulate that a rupture was caused by the microcatheter or guidewire at the beginning of the procedure. Another patient presented with brain stem infarction caused by a giant fusiform vertebrobasilar aneurysm. He did not recover after bilateral occlusion treatment and died 1 month after discharge. Although an autopsy was not performed, it was assumed that the death was a result of the attempted treatment.

Midterm angiographic outcome

Of the 86 patients who survived the intervention (96.6%), a follow-up angiogram was available in 76 patients (88.4%) at an average of 6.8 months (range: 1–36 months). These 76 patients had a total of 78 aneurysms. A total of 70 patients (92.1%) remained stable during the entire observation period. Six aneurysms in six patients showed recanalization, all of which were treated initially with stent-assisted coiling. An additional patient received follow-up CT angiographic imaging at 6 months, which showed no evidence of recanalization. Of the nine aneurysms treated with stenting alone, follow-up angiography was obtained in all cases, six of which all demonstrated complete aneurysm occlusion and three demonstrated no change without recanalization observed up to 2 years.

Long-term clinical outcome

A follow-up neurological examination was performed in 86 surviving patients at an average of 22 months (range: 1–48 months). Eighty-four of the 89 surviving patients (94.4%) showed significant improvement in their presenting symptoms and had no new procedure-related deficit. Two patients with major permanent morbidity (2.2%) were previously discussed.

Discussion

The primary goal of endovascular therapy of unrupture intracranial aneurysms is the prevention of hemorrhage and

its devastating consequences.[10-12] The study by Wiebers *et al*.[9] reported 5-year cumulative rupture rates for patients who did not have a history of subarachnoid hemorrhage with aneurysms located in posterior circulation and posterior communicating artery aneurysms of 2.5%, 14.5%, 18.4%, and 50% for aneurysms less than 7 mm, 7–12 mm, 13–24 mm, and > 25 mm, respectively. In the context of this poor natural history, the results presented here for UPCIAs indicate that endovascular therapy confers a protective effect. We encountered 16.7% hemorrhage rate and 25% mortality rate in giant UPCIAs associated with endovascular therapy. This corresponds to a yearly bleeding rate of 11.5% per year, a rate similar to that reported in other endovascular series.[13] Until recently, in parallel to the endovascular treatment of ruptured aneurysms, coiling of unruptured intracranial aneurysms evolved as an obvious minimally invasive alternative to microsurgical clipping, one that would probably be better tolerated by the patient. Most published studies on the safety and efficacy of endovascular treatment have been conducted on unruptured aneurysms,[10-22] and treatment results were extrapolated to the management of UPCIAs even though proof of its midterm efficacy was not yet available.[3,4] Robust data concerning the treatment of UPCIAs were not available and the information available today is still based on a small number of treated patients, and data on the midterm stability and protection against SAH are lacking.[1,3-7,13] As future prevention of SAH is the primary goal of treatment, the availability of these data is vital.

Risk of treatment

In the present study the overall procedure-related mortality was 3.4%, and the permanent morbidity was 2.2%. This morbidity and mortality rates were comparable to that of prospective multicenter and retrospective community-based studies on unruptured intracranial aneurysms. Two community-based studies found adverse events in more than 10% of the treated patients although the mortality rate was low.[23,24] In ISUIA, the prospectively evaluated mortality rate was 3.4% and the morbidity rate was 6.4%.[9] Another prospective multicenter study reported mortality and morbidity rates of 5.4%.[20] This morbidity and mortality rates were higher than that of previously published single-center studies on unruptured intracranial aneurysms that report mortality rates of 0–1.7% and morbidity rates of 0.27–7.7%.[11,14,17,21,22,25] In the only existing meta-analysis on the endovascular treatment of unruptured aneurysms to date, Lanterna *et al*.[10] calculated a mortality rate of 0.6% for 1,379 available patients; the average morbidity rate was 7.0% based on 794 available patients. One reason for the higher morbidity and mortality reported in these studies could be a publication bias in single-center studies that may underestimate the complication rate of a technique.[26] The angiographic and clinical outcomes of endovascular treatment of UPCIAs are usually not systematically evaluated in the single-center studies. These morbidity and mortality rates of endovascular treatment of UPCIAs included in previous studies are from 0.27% to 7.7%.[4,14,21,27]

Midterm stability and effectiveness of treatment

Whether midterm protection against SAH is achieved by endovascular treatment is not clear because there are almost no data available to date on this issue.[10] The bleeding rate of ruptured aneurysms after endovascular intervention is somewhat better documented and in larger series was about 1% in the first year after treatment.[28] But even these studies provide no long-term data. In Cerebral Aneurysm Rerupture After Treatment (CARATL) study,[29] 1 postembolization bleeding in 299 patients treated with coil embolization was included in their analysis. The mean follow-up of coiled patients was 3.7 years, representing 1,089 patient-years. They calculated an overall annual bleeding rate of 0.11% after 1 year for coiling. This result for rebleeding was similar to those of International Subarachnoid Aneurysm Trial (ISAT), in which the annual rates of rerupture after 1 year were 0.21% for those treated with coiling.

Lanterna *et al*.[10] found 13 postembolization bleedings in 703 patients in 30 studies included in their analysis. The average follow-up of the single studies ranged 0.5–3.8 years; the mean follow-up of all studies was 2.0 years, representing 1,416 patient-years. Lanterna *et al*. calculated an overall annual bleeding rate of 0.9%. This rate seems relatively high compared to the annual bleeding risk for unruptured aneurysms found in observational studies. In their analysis, only partially occluded aneurysms larger than 10 mm had bled. For 85 aneurysms larger than 10 mm, they found an annual bleeding rate of 3.5%. In the study of Standhardt *et al*.,[13] three cases of giant aneurysms of the posterior circulation were ruptured during follow-up. The calculated annual risk of rupture for this subgroup was 11.5% per year, and was similar to that reported by ISUIA,[9] which estimated the risk of rupture for this group at 10% per year. In our study, there were three cases of death. All patients had giant aneurysms of the posterior circulation, and two aneurysms could not be occluded completely through embolization. The calculated mortality rate of this subgroup was 25% per year. This result was even more disappointing. Consequently, coil embolization of this group of aneurysms has to be strongly questioned. Whether modified endovascular treatment strategies, such as flow diversion or bioactive coils, might help to attain better results is not clear because there are almost no data available to date on this issue. Several questions remain unanswered related to the incidence and mechanisms of aneurysm rupture after treatment with flow diverters as shown in our patients, fate of small perforating vessels, and long-term patency rates. But as long as there is no better midterm stability on the horizon for this group, well-established techniques such as microsurgical clipping or parent artery occlusion seem appropriate, if technically feasible.[30] In contrast to the poor midterm result in giant aneurysms of the posterior circulation, there was no rupture in the nongiant aneurysm group.

As demonstrated also by others,[8] midterm stability cannot be achieved for all aneurysms treated by coiling. Aneurysm diameter and neck size were found to have an impact on midterm stability. The angiographic follow-up of treated patients, therefore, seems mandatory as partially occluded aneurysms might be at risk of future rupture. In the case of relevant aneurysm reperfusion, additional coiling, microsurgical clipping, or parent artery occlusion should be considered.

Conclusion

Endovascular treatment for UPCIAs is a safe therapy with low morbidity and mortality in recent years. The midterm data for nongiant aneurysms give rise to the hope that the primary goal of prevention of SAH can be achieved. For giant aneurysms of the posterior circulation, periprocedural results were disappointing. Well-established treatment alternatives

such as microsurgical clipping or parent artery occlusion must be considered.

Financial support and sponsorship
Nil.

Conflicts of interest
There are no conflicts of interest.

References

1. Molyneux A, Kerr R, Stratton I, Sandercock P, Clarke M, Shrimpton J, *et al*.; International Subarachnoid Aneurysm Trial (ISAT) Collaborative Group. International Subarachnoid Aneurysm Trial (ISAT) of neurosurgical clipping versus endovascular coiling in 2143 patients with ruptured intracranial aneurysms: A randomised trial. Lancet 2002;360:1267-74.
2. Eftekhar B, Morgan MK. Preoperative factors affecting the outcome of unruptured posterior circulation aneurysm surgery. J Clin Neurosci 2011;18:85-9.
3. Kim BM, Kim SH, Kim DI, Shin YS, Suh SH, Kim DJ, *et al*. Outcomes and prognostic factors of intracranial unruptured vertebrobasilar artery dissection. Neurology 2011;76:1735-41.
4. Pandey AS, Koebbe C, Rosenwasser RH, Veznedaroglu E. Endovascular coil embolization of ruptured and unruptured posterior circulation aneurysms: Review of a 10-year experience. Neurosurgery 2007;60:626-37.
5. Lv X, Lv M, Li Y, Yang X, Jiang C, Wu Z. Endovascular treatment of ruptured and unruptured vertebral artery aneurysms. Neuroradiol J 2011;24:677-86.
6. Lv X, Jiang C, Li Y, Wu Z. Clinical outcomes of lower cranial nerve palsies caused by vertebral artery-posteroinferior cerebellar artery aneurysms after endovascular embolization. Neurol Res 2010;32:796-800.
7. Lv X, Jiang C, Li Y, Wu Z. Clinical outcomes of ruptured and unruptured vertebral artery-posterior inferior cerebellar artery complex dissecting aneurysms after endovascular embolization. AJNR Am J Neuroradiol 2010;31:1232-5.
8. Raymond J, Guilbert F, Weill A, Georganos SA, Juravsky L, Lambert A, *et al*. Long-term angiographic recurrences after selective endovascular treatment of aneurysms with detachable coils. Stroke 2003;34:1398-403.
9. Wiebers DO, Whisnant JP, Huston J 3rd, Meissner I, Brown RD Jr, Piepgras DG, *et al*. International Study of Unruptured Intracranial Aneurysms Investigators. Unruptured intracranial aneurysms: Natural history, clinical outcome, and risks of surgical and endovascular treatment. Lancet 2003;362:103-10.
10. Lanterna LA, Tredici G, Dimitrov BD, Biroli F. Treatment of unruptured cerebral aneurysms by embolization with Guglielmi detachable coils: Case-fatality, morbidity, and effectiveness in preventing bleeding-a systematic review of the literature. Neurosurgery 2004;55:767-78.
11. Roy D, Milot G, Raymond J. Endovascular treatment of unruptured aneurysms. Stroke 2001;32:1998-2004.
12. Gonzalez N, Murayama Y, Nien YL, Martin N, Frazee J, Duckwiler G, *et al*. Treatment of unruptured aneurysms with GDCs: Clinical experience with 247 aneurysms. AJNR Am J Neuroradiol 2004;25:577-83.
13. Standhardt H, Boecher-Schwarz H, Gruber A, Benesch T, Knosp E, Bavinzski G. Endovascular treatment of unruptured intracranial aneurysms with Guglielmi detachable coils: Short- and long-term results of a single-centre series. Stroke 2008;39:899-904.
14. van Rooij WJ, de Gast A, Sluzewski M, Nijssen PC, Beute GN. Coiling of truly incidental intracranial aneurysms. AJNR Am J Neuroradiol 2006;27:293-6.
15. Brinjikji W, Rabinstein AA, Nasr DM, Lanzino G, Kallmes DF, Cloft HJ. Better outcomes with treatment by coiling relative to clipping of unruptured intracranial aneurysms in the United States, 2001-2008. AJNR Am J Neuroradiol 2011;32:1071-5.
16. Brinjikji W, Rabinstein AA, Lanzino G, Kallmes DF, Cloft HJ. Patient outcomes are better for unruptured cerebral aneurysms treated at centers that preferentially treat with endovascular coiling: A study of the national inpatient sample 2001-2007. AJNR Am J Neuroradiol 2011;32:1065-70.
17. Gallas S, Drouineau J, Gabrillargues J, Pasco A, Cognard C, Pierot L, *et al*. Feasibility, procedural morbidity and mortality, and long-term follow-up of endovascular treatment of 321 unruptured aneurysms. AJNR Am J Neuroradiol 2008;29:63-8.
18. Hwang SK, Hwang G, Oh CW, Jin SC, Park H, Bang JS, *et al*. Endovascular treatment for unruptured intracranial aneurysms in elderly patients: Single-center report. AJNR Am J Neuroradiol 2011;32:1087-90.
19. Unruptured intracranial anurysms-risk of rupture and risks of surgical intervention. International Study of Unruptured Intracranial Aneurysms Investigators. N Engl J Med 1998;339:1725-33.
20. Pierot L, Spelle L, Vitry F; ATENA Investigators. Immediate clinical outcome of patients harboring unruptured intracranial aneurysms treated by endovascular approach: Results of the ATENA study. Stroke 2008;39:2497-504.
21. Im SH, Han MH, Kwon OK, Kwon BJ, Kim SH, Kim JE, *et al*. Endovascular coil embolization of 435 small asymptomatic unruptured intracranial aneurysms: Procedural morbidity and patient outcome. AJNR Am J Neuroradiol 2009;30:79-84.
22. Higashida RT, Lahue BJ, Torbey MT, Hopkins LN, Leip E, Hanley DF. Treatment of unruptured intracranial aneurysms: A nationwide assessment of effectiveness. AJNR Am J Neuroradiol 2007;28:146-51.
23. Johnston SC, Dudley RA, Gress DR, Ono L. Surgical and endovascular treatment of unruptured cerebral aneurysms at university hospitals. Neurology 1999;52:1799-805.
24. Johnston SC, Zhao S, Dudley RA, Berman MF, Gress DR. Treatment of unruptured cerebral aneurysms in California. Stroke 2001;32:597-605.
25. Park HK, Horowitz M, Jungreis C, Genevro J, Koebbe C, Levy E, *et al*. Periprocedural morbidity and mortality associated with endovascular treatment of intracranial aneurysms. AJNR Am J Neuroradiol 2005;26:506-14.
26. Yoshimoto Y. Publication bias in neurosurgery: Lessons from series of unruptured aneurysms. Acta Neurochir (Wien) 2003;145:45-8.
27. van Rooij WJ, Sluzewski M. Procedural morbidity and mortality of elective coil treatment of unruptured intracranial aneurysms. AJNR Am J Neuroradiol 2006;27:1678-80.
28. Leung CH, Poon WS, Yu LM; International Subarachnoid Aneurysm Trial. The ISAT trial. Lancet 2003;361:430-2.
29. CARAT Investigators. Rates of delayed rebleeding from intracranial aneurysms are low after surgical and endovascular treatment. Stroke 2006;37:1437-42.
30. Sanai N, Tarapore P, Lee AC, Lawton MT. The current role of microsurgery for posterior circulation aneurysms: A selective approach in the endovascular era. Neurosurgery 2008;62:1236-53.