

Original Article

Impact of different surgical methods for endovascular embolization of intracranial wide-necked aneurysms on patient prognosis and cognitive function

Jinfeng Pang¹, Changfu Zhao¹, Airong Zhang¹, Wenjun Pang², Xianbin Ning¹

¹Department of Neurosurgery, The Affiliated Hospital of Beihua University, Jilin 132011, China; ²Department of Clinical Medicine, Yanbian University, Yanbian 133002, China

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Abstract: The aim of the current study was to observe the clinical effects of endovascular embolization with double microcatheter and stent-assisted coil embolization for treatment of intracranial wide-necked aneurysms, examining its influence on patient cognitive function. A total of 128 patients with intracranial wide-necked aneurysms were randomly divided into the observation group (OBS) and control group (CON), comparing the impact of different embolization methods on cognitive function. MMSE computational power, attention, memory, orientation, language ability, and recall levels in group OBS were significantly higher than those in group CON ($P < 0.01$). Total postoperative complications in group OBS were 4.7%, statistically lower than those in group CON (17.2%) ($P < 0.05$). Double microcatheter embolization for endovascular embolization provides significant clinical effects. These may improve patient postoperative cognitive dysfunction, demonstrating high clinical value.

Keywords: Intracranial aneurysms, embolization, double microcatheter technique, cognitive impairment

Introduction

Endovascular embolization has become one of the main treatment methods in the clinical treatment of intracranial wide-necked aneurysms [1-3]. Generally, the circuitous phenomenon of intracranial arteriosclerosis in patients is serious. This leads to wide-necked aneurysms and poor stability of microcatheters and guide tubes in the blood vessels. Thus, it is difficult to achieve complete embolization [4]. Stent-assisted and balloon embolization techniques have been widely used in clinical treatment. They can effectively protect the neck from aneurysms and significantly improve the clinical cure rate of patients. However, there are still some defects and limitations in the application process [1, 5, 6]. The double microcatheter technique has been widely used in clinic in recent years. During this procedure, two microcatheters are placed in the aneurysm lumen, simultaneously. Spring coils can be inserted by these two microcatheters alternately [7, 8]. The coils can be released after stabilization and

the microcatheters can be withdrawn after achieving satisfactory embolization. At present, there are few reports concerning changes in cognitive function in patients after endovascular embolization with double microcatheters [9]. Therefore, the present study used the double microcatheter technique to perform endovascular embolization, aiming to observe clinical effects and cognitive function changes.

Materials and methods

General information

A total of 128 patients with intracranial wide-necked aneurysms, diagnosed by pathological and imaging examinations, from April 2013 to March 2018, were selected and divided into group OBS and group CON, according to the random envelope method (with 64 cases in each group). In group OBS, there were 33 males and 31 females, aged 45-78 years, with an average age of (62.18±2.84) years. Patients included 22 cases of anterior communicating aneurysms, 23 cases of posterior communicat-

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ing aneurysms, 7 cases of posterior cerebral aneurysms, and 12 cases of middle cerebral aneurysms. The carotid width of aneurysms was 4-9 mm and the diameter of aneurysms was 4-12 mm. According to Hunt-Hess classification scores [5], there were 5 cases of grade IV, 23 cases of grade III, 28 cases of grade II, and 8 cases of grade I. Group CON consisted of 30 males and 34 females, aged 48-81 years, with an average age of (64.26±2.73) years. Patients included 21 cases of anterior communicating aneurysms, 24 cases of posterior communicating aneurysms, 6 cases of posterior cerebral aneurysms, and 13 cases of middle cerebral aneurysms. The carotid width of the aneurysms was 5-10 mm and the diameter of the aneurysms was 4-11 mm. According to Hunt-Hess classification scores, the aneurysms were divided into 7 cases of grade IV, 20 cases of grade III, 27 cases of grade II, and 10 cases of grade I. There were no statistical differences in terms of gender, age, Hunt-Hess classification, and disease condition between the two groups ($P > 0.05$). Thus, the two groups were comparable. The present study was conducted in accordance with the Declaration of Helsinki, obtaining approval from the Ethics Committee of Beihua University. Written informed consent was obtained from all participants.

Inclusion criteria and exclusion criteria

Inclusion criteria: (1) Patients in this study were informed of the study and provided informed consent; (2) All clinical data and follow-up data were complete; (3) Clinical symptoms of the patients met the diagnostic criteria for intracranial wide-necked aneurysms; (4) Results of angiography tests showed that the patients were suitable for surgical treatment; and (5) Patients had no traces of diabetes or hypertension. *Exclusion criteria:* (1) Allergic to drugs used in this study; (2) With abnormal liver/kidney function; (3) With multiple intracranial aneurysms; and (4) Voluntarily applied for withdrawal from this study or lack of follow-up data.

Methods

Before the operation, each patient underwent drug intervention. Patients with ruptured aneurysms were given 300 mg of Bay-aspirin tablets (Bayer Medical and Health Co., Ltd., J20 1, 3007 8) and 300 mg of clopidogrel tablets (Shenzhen Xinlitai Pharmaceutical Co., Ltd.,

H2013, 542) 5 hours before the operation. Patients with unruptured aneurysms were given 100 mg of Bay-aspirin tablets and 75 mg of clopidogrel tablets 3 days before the operation. Group OBS was treated with double microcatheters embolization, while group CON was treated with intracranial stent-assisted coil embolization.

Surgery procedure

Group OBS: After general anesthesia, as well as femoral artery puncture and intubation, one 6F guide tube was inserted into the carotid artery, with the tip inserting into the vertical part of C2 petrous. A total of 70 U/KG heparin sodium was injected intravenously and 1000 U heparin sodium was dripped, intravenously, every 1 hour for enhancement. According to 3D images collected by 3D-DSA, the relationship between the aneurysm and aneurysm-carrying artery was analyzed, aiming to select the best working angle for displaying the neck of the aneurysm and aneurysm-carrying branch. Guided by nerve microwire and path mapping, the appropriately shaped microcatheter was placed in the aneurysm lumen and stabilized. According to the conditions of the aneurysm, appropriate coils were selected, maintaining the stability of the aneurysm. At the same time, a Y-shaped valve was attached to the side wall of the tail end of the guide tube, guiding another microcatheter entering the lesion area of the aneurysmal cavity. Combined with the conditions of the aneurysm and previous embolization, appropriate coils were selected for continuous insertion. Two microcatheters were alternately filled with coils. The coils were released, alternately, until the filling effects were satisfactory.

Group CON: After trachea cannula and general anesthesia, together with intravenous injections of 70 U/KG heparin sodium and intravenous drip of 1000 U heparin sodium every 1 hour for enhancement, one 8F guide tube was inserted into the carotid artery. The tip was inserted into C2, according to 3D images collected by 3D-DSA. The microcatheter was transported in the intracranial stent system. When the diameter of the aneurysm-carrying artery was more than 1 mm, the stent was placed 0.5 cm across the aneurysmal neck. The appropriately shaped spring coil microca-

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Table 1. Comparison of clinical effects and total effective rate between the two groups (n=64, n, %)

Group	Marked improvement	Certain improvement	Ineffective	Total cases with improvement
OBS	34 (53.1)	27 (42.2)	3 (4.7)	61 (95.3)
CON	35 (54.7)	24 (37.5)	5 (7.8)	59 (92.2)
Corrected χ^2	0.1333			
P	0.715			

Table 2. Comparison of incidence rates of postoperative complications between the two groups (n=64, n)

Group	Cerebral Vasospasm	Hydrocephalus	Epilepsy	Cerebral ischemia	Total incidence
OBS	1 (1.56)	1 (1.56)	0 (0.0)	1 (1.56)	3 (4.7)
CON	3 (4.68)	2 (3.12)	1 (1.56)	5 (7.81)	11 (17.2)
Corrected χ^2	3.929				
P	0.047				

theter was placed in the aneurysm lumen and the stent was half-released. When the neck of the aneurysm was covered by a uniform speed of hand-push angiography, one appropriate spring coil was selected and placed in the lumen of the aneurysm. All stents were released after achieving satisfactory results.

Observation indexes

The present study followed-up the patients for one year, aiming to observe clinical efficacy and complications. At 1 year after the operation, cognitive function levels of the patients were evaluated by Mini-Mental State Examination (MMSE). This exam contains five items, including memory, recall, calculation, attention, orientation, and language. It classifies patients into severe disorder (score < 9 points), moderate disorder (score 10-20 points), mild disorder (score 21-27 points), and normal (score > 27 points) categories. Evaluation of the curative effects of patients were divided into three categories: 1) Marked improvement of clinical symptoms, with a reduction of the aneurysm > 60%; 2) Certain improvement of clinical symptoms, with a reduction of the aneurysm 20%-59%; and 3) Ineffective, without significant improvement or with deterioration of clinical symptoms or death, with no significant reduction or even increase of the aneurysm. The total effective rate is equal to (cases with improvement + cases with effectiveness)/total cases * 100%.

Statistical methods

Data was analyzed using SPSS 19.0. Counting data were compared using χ^2 tests, while measurement data were compared using independent-sample t tests. $P < 0.05$ indicates statistical significance.

Results

There were no significant differences regarding clinical efficacy and total effective rates between the two groups ($P > 0.05$), **Table 1**. Total effective rates of the two groups were 95.3% (Group OBS) and 92.2% (Group CON), respectively, indicating no statistical morpho-

logical significance between Group OBS and Group CON in cerebral angiography examinations one year after the operation. For irregularly-shaped aneurysms, dual microcatheters were used to pack aneurysms in different areas. This allows the aneurysms to be packed tightly without disturbing the aneurysm. Although stent-assisted aneurysm packing has made the wide neck of the aneurysm into a relatively narrow-neck aneurysm, for irregular aneurysms, single microcatheter packing cannot achieve sub-regional packing. The packing is not dense. Moreover, postoperative anti-platelet aggregation drugs were orally administered regularly. This makes possible the recurrence of aneurysms. For recurrent aneurysms, there is often difficulty entering microcatheters into the aneurysm due to the stent implantation. This will increase the difficulty of re-operations.

Comparison of postoperative complications

CT and MRI results of group OBS showed 1 case of cerebral vasospasms, 0 cases of epilepsy, 1 case of hydrocephalus, and 1 case of transient cerebral ischemia. Incidence of complications was 4.7% (3/64). Group CON had 3 cases of cerebral vasospasms, 2 cases of hydrocephalus, 1 case of epilepsy, 4 cases of transient cerebral ischemia, and 1 case of permanent cerebral ischemia. Incidence of complications was 17.2% (11/64). Incidence of complications in group OBS was statistically lower

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Table 3. Comparison of MMSE between the two groups (n=64, $\bar{x} \pm s$, points)

Group	Computation and attention	Memory	Orientation	Language	Recall
OBS	27.5±0.6	23.4±0.7	26.8±0.6	26.7±0.5	25.9±0.5
CON	15.2±0.5	13.7±0.6	13.2±0.5	16.3±0.5	13.6±0.4
t	125.988	84.169	139.304	117.663	153.675
P	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001

Table 4. Comparison of postoperative IQ between the two groups according to Wechsler Adult Intelligence Scale (n=64, n)

Group\age	45-54	55-64	65-74	75-84
OBS	101	97	93	92
CON	92	90	86	80
P	< 0.05	< 0.05	< 0.05	< 0.05

than that in group CON ($P < 0.05$); **Table 2.** Results showed that Group OBS had 2 cases of cerebral vasospasm (1 case) + cerebral ischemia (1), while Group CON had 8 cases of cerebral ischemia (3 case) + cerebral ischemia (5), indicating that the stent used in Group CON resulted in higher occlusion of the branch vessels of the tumor-bearing artery, as well as insufficient blood supply to the distal vessels of the tumor-bearing artery. Moreover, incidence of vasospasms caused by stent implantation was higher than that in Group OBS. These factors led to a higher incidence of cognitive impairment in Group CON than Group OBS. Stent-assisted coil embolization had a higher incidence of intraoperative and postoperative complications (cerebral infarction in common cases) than Group OBS. Perhaps this is because the procedure of stent-assisted coil embolization is more complicated. Intraoperative bleeding is more likely to occur, inducing cerebral vasospasms and cerebral infarction caused by the detachment of plaques in blood vessels. Additionally, prolonged surgical times will increase the chance of thrombosis. **Table 3** confirms that the cognitive impairment in Group CON was higher than that in Group OBS, regarding postoperative complications.

MMSE scores in group OBS were significantly higher than those in group CON ($P < 0.01$); **Table 3.** In detail, there were significant differences in computation and attention, memory, orientation, and language recall between these

two groups ($P < 0.01$). This is an interesting result. Cognitive impairment was higher in Group CON than in Group OBS. After reviewing MRI or CT scans, there were more cases of cerebral infarction in Group CON than in Group OBS. It was speculated that the metal structure of the stent placed on the tumor-bearing artery in Group CON blocked the

branch vessels of the tumor-bearing artery. Additionally, covering the stent by the endometrium of the blood vessel caused the stenosis of the tumor-bearing artery, resulting in insufficient blood supply to the distal end of the tumor-bearing artery. However, patients in Group OBS were only packed aneurysms, during which period the tumor-bearing artery was not disturbed. Insufficient blood supply to the distal artery of the tumor-bearing arteries did not occur. Thus, there were fewer cases of cerebral infarction.

Comparison of postoperative IQ between the two groups according to Wechsler adult intelligence scale

OBS was statistically higher than that in group CON ($P < 0.05$) during the four age stages (45-54, 55-64, 65-74, 75-84); **Table 4.** Results showed that, as age increased, the IQ of the patients in both groups showed a downward trend. The IQ of patients in Group CON was lower than that in Group OBS in different age group. This also indicated that higher complications in Group CON after surgery led to IQ being affected.

Results of 1-5 years follow-ups

According to the number of recurrence and related cerebral ischemia, OBS was statistically lower than that in group CON ($P < 0.05$). According to satisfaction of patients, OBS was statistically higher than that in group CON ($P < 0.05$); **Table 5.**

Patients in Group OBS had lower postoperative complications than those in Group CON. Moreover, there were fewer cases of postoperative cognitive impairment and less impact on IQ. These factors improved patient quality of life levels, leading to higher postoperative satisfaction in Group OBS than in Group CON.

Table 5. Results of 1-5 years of follow-ups between the two groups (n=64, n)

Results of 1-5 years follow-up	Number of follow-up	Numbers of recurrence	Related cerebral ischemia	Satisfaction of patients
OBS	60	1	1	97%
CON	61	5	5	82%

Discussion

Intracranial wide-necked aneurysms mainly include relatively wide-necked aneurysms and absolute wide-necked aneurysms. Interventional therapy is a recognized option for treatment of wide-necked aneurysms. However, there are still many problems, such as tumor neck residual, embolic material displacement, and recanalization [10]. Intracranial aneurysms treated with neuro-interventional techniques have achieved significant clinical effects [11-13]. In the treatment of wide-necked aneurysms, the relapse rate is high and the embolization rate is low using micro-coils alone, which is the difficulty of treatment at present [14, 15]. For wide-necked aneurysms, stent-assisted, balloon-assisted, double-catheter, and various basket-forming techniques are the mainstream methods [16]. However, within 48 hours of rupturing, there are still many problems worth exploring regarding the choice of endovascular treatment.

In recent years, the passable nature and softness of high compliance balloon HyperForm and hyper-glide have enabled the balloon to reach most of the aneurysms. Balloon-assisted technology can avoid the impact of antiplatelet drugs in the acute phase, but the controllability of operation remains to be discussed [17]. In the process of blocking blood flow by such balloons, most of the blocking time is less than 5 minutes. However, whether 5 minutes will affect the brain tissue, causing irreversible damage or thrombosis, remains controversial [18]. When the coil is filled up and withdrawn from the balloon, it is difficult to judge whether the coil is stable and if it will not fall out in the face of blood flow impact. This is often difficult to judge during the operation.

Advantages of stents in guiding blood flow and covering the neck of aneurysms have been generally acknowledged. The rise of stent technology has greatly promoted endovascular technology, making it possible to treat many

complex aneurysms that could not be treated in the past. However, it also results in some new complications [19]. Currently, Solitaire AB stent, Enterprise stent, Neuroform stent, Leo stent have provided more choices for surgeons. However,

there are still different opinions on whether to use stents for acute hemorrhaging within 48 hours. The main disadvantages are as follows: (1) It is difficult to transport the stent jacket through microcatheters. In tortuous vessels or large aneurysms, the transfer of the stent jacket needs repeated exchange. Thus, it may not be completed sometimes; (2) Antiplatelet drugs should be prepared before the perioperative period, together with anticoagulant and continuous antiplatelet drugs after the operation. This increases the risk of bleeding and the difficulty of treatment after bleeding. Re-eruption after acute stent implantation is often fatal; (3) For different individuals, the degree of antiplatelets is also different. According to the current commonly adopted drug dosage, it is inevitable that a few cases may have stent thrombosis or excessive bleeding caused by antiplatelet drugs; and (4) If aneurysm ruptures occur, it is difficult to neutralize antiplatelet drugs when a craniotomy is needed. This results in intraoperative hemostasis difficulties and postoperative re-bleeding.

Facing acute wide-necked aneurysms, the advantages of double catheters are obvious: (1) The 6F catheter can hold two microcatheters and the operation is not complicated; (2) Routine heparinization and postoperative neutral treatment can significantly reduce the risk of bleeding. Once craniotomy is required, such treatment is easier; (3) Compared with a single catheter, simultaneous embolization using two coils can achieve easier co-operation and repeated adjustments can form more complex shapes of aneurysms. Thus, the neck and body of aneurysms can be filled better; and (4) In the process of double-catheter tamponade, the winding and extrusion between coils always exist. Thus, the possibility of postoperative compression of coils is reduced. The two catheters are tampered in different areas of aneurysms, avoiding the filling dead angle in aneurysms and making the filling more uniform and complete.

Double microcatheter technology may reduce incidence of cognitive impairment

In recent years, with the development of treatment techniques, double microcatheter technology has been widely used in clinic. It has been pointed out that, in the treatment of intracranial wide-carotid aneurysms, the double microcatheter technique can be used as the main means and can improve cognitive impairment in patients [7, 20]. Some scholars have used different surgical methods to treat intracranial wide-carotid aneurysms. It has been found that the double microcatheter technique has high stability, accurate packing, and high balance when releasing the coil catheters. This method can effectively reduce incidence of complications, such as vasospasms and ischemia [8, 21, 22]. Some scholars have pointed out that the cognitive function of patients with wide-necked intracranial aneurysms is only about 1/4 of that in normal patients [23, 24]. The risk of aneurysm rupturing and hemorrhaging can be reduced by double microcatheter embolization without antiplatelet therapy. Some patients with good postoperative conditions do not need postoperative treatment, such as decompression of bone flaps or outdoor drainage, improving the postoperative cognitive ability of patients [25-27]. Surgical methods may affect the prognosis and cognitive function of patients [28, 29]. Results of the current study show that cognitive function levels in group OBS were significantly better than those in group CON. The total incidence of complications was significantly reduced. Compared with the stent-assisted technique, the double microcatheter technique has the advantages of simplicity, convenience, and low costs. It can reduce difficulties in placement and embolization of the microcatheter and guide tube, effectively protecting occluded aneurysms and nearby vascular branches.

In summary, use of the double microcatheter technique for endovascular embolization has significant therapeutic effects. This method can reduce operative complications and improve postoperative cognitive dysfunction. Therefore, this method provides high clinical application value. However, the number of clinical samples in this study was relatively small. The present topic should be further analyzed, expanding the number of clinical samples, aiming to confirm present results.

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Disclosure of conflict of interest

None.

Address correspondence to: Xianbin Ning, Department of Neurosurgery, The Affiliated Hospital of Beihua University, Jilin 130011, China. Tel: +86-432-62166429; Fax: +86-432-62166429; E-mail: xianbinning@163.com

References

- [1] Ohshima T, Miyachi S, Matsuo N, Kawaguchi R, Niwa A, Maejima R, Isaji T and Takayasu M. Efficacy of the proximal balloon flow control method for endovascular coil embolisation as a novel adjunctive technique: a retrospective analysis. *Interv Neuroradiol* 2018; 24: 375-378.
- [2] Kawabata Y, Nakazawa T, Fukuda S, Kawarazaki S, Aoki T, Morita T and Tsukahara T. Endovascular embolization of branch-incorporated cerebral aneurysms. *Neuroradiol J* 2017; 30: 600-606.
- [3] Altschul D, Biswas A, Nakhla J, Echt M and Gordon D. Novel double catheter technique with detachable microcatheter for the treatment of arteriovenous malformations: a technical note. *Surg Neurol Int* 2016; 7: S1072-S1074.
- [4] Heo HY, Ahn JG, Ji C and Yoon WK. Selective Temporary stent-assisted coil embolization for intracranial wide-necked small aneurysms using solitaire AB retrievable stent. *J Korean Neurosurg Soc* 2019; 62: 27-34.
- [5] Sgreccia A, Coskun O, Di Maria F, Rodesch G and Consoli A. Fenestration of the supraclinoid segment of the ICA and associated aneurysms: a case report with literature review. *Acta Neurochir (Wien)* 2018; 160: 1143-1147.
- [6] Cai ZQ, Chai SH, Wei XL, You KZ, Li J and Zhang DM. Comparison of postsurgical clinical sequences between completely embolized and incompletely embolized patients with wide-necked intracranial aneurysms treated with stent assisted coil embolization technique: a STROBE-compliant study. *Medicine (Baltimore)* 2018; 97: e10987.
- [7] Juszkat R, Stanisławska K, Kopińska K, Liebert W and Moskal J. Embolisation of internal carotid artery aneurysm using the double microcatheter technique - a case report. *Pol J Radiol* 2015; 80: 191-194.
- [8] Cho YD, Rhim JK, Kang HS, Park JJ, Jeon JP, Kim JE, Cho WS and Han MH. Use of triple microcatheters for endovascular treatment of wide-necked intracranial aneurysms: a single center experience. *Korean J Radiol* 2015; 16: 1109-1118.
- [9] Lee JW, Woo JM, Lim OK, Jo YE, Kim JK, Kim ES and Lee DH. Enlarged parent artery lumen at aneurysmal-neck segment in wide-necked dis-

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- tal internal carotid artery aneurysms. *Neurointervention* 2015; 10: 82-88.
- [10] Lee CY and Kim CH. Very late stent thrombosis following the placement of a crossing Y-stent with dual closed-cell stents for the coiling of a wide-necked aneurysm. *J Neurointerv Surg* 2015; 7: e8.
- [11] Lee SH, Park IS, Lee JM, Lee K, Park H and Lee CH. Stent-assisted coil embolization using only a glycoprotein IIb/IIIa inhibitor (Tirofiban) for ruptured wide-necked aneurysm repair. *J Cerebrovasc Endovasc Neurosurg* 2018; 20: 14-23.
- [12] Ito H, Onodera H, Wakui D, Uchida M, Sase T, Morishima H, Oshio K and Tanaka Y. The “temporary caging” technique for catheter navigation in patients with intracranial wide-necked aneurysms. *Int J Clin Exp Med* 2015; 8: 11214-11219.
- [13] Rahal JP, Dandamudi VS, Safain MG and Malek AM. Double waffle-cone technique using twin Solitaire detachable stents for treatment of an ultra-wide necked aneurysm. *J Clin Neurosci* 2014; 21: 1019-1023.
- [14] Wolfe SQ, Farhat H, Moftakhar R, Elhammady MS and Aziz-Sultan MA. Intraaneurysmal balloon assistance for navigation across a wide-necked aneurysm. *J Neurosurg* 2010; 112: 1222-1226.
- [15] Lee CY and Kim CH. Very late stent thrombosis following the placement of a crossing Y-stent with dual closed-cell stents for the coiling of a wide-necked aneurysm. *BMJ Case Rep* 2014; 2014.
- [16] Sedat J, Chau Y, Mondot L, Vargas J, Szapiro J and Lonjon M. Endovascular occlusion of intracranial wide-necked aneurysms with stenting (Neuroform) and coiling: mid-term and long-term results. *Neuroradiology* 2009; 51: 401-409.
- [17] Youn SO, Lee JI, Ko JK, Lee TH and Choi CH. Endovascular treatment of wide-necked intracranial aneurysms using balloon-assisted technique with hyper form balloon. *J Korean Neurosurg Soc* 2010; 48: 207-212.
- [18] Sluzewski M, van Rooij WJ, Beute GN and Nijsen PC. Balloon-assisted coil embolization of intracranial aneurysms: incidence, complications, and angiography results. *J Neurosurg* 2006; 105: 396-399.
- [19] van Rooij WJ, Sluzewski M, Beute GN and Nijsen PC. Procedural complications of coiling of ruptured intracranial aneurysms: incidence and risk factors in a consecutive series of 681 patients. *AJNR Am J Neuroradiol* 2006; 27: 1498-1501.
- [20] Wong GKC, Mak JSY, Wong A, Zheng VZY, Poon WS, Abrigo J and Mok VCT. Minimum clinically important difference of montreal cognitive assessment in aneurysmal subarachnoid hemorrhage patients. *J Clin Neurosci* 2017; 46: 41-44.
- [21] Sirakov S, Panayotova A, Sirakov A, Penkov M, Minkin K and Hristov H. Using the pCANvas neck-bridging device in treating a wide-necked aneurysm of the basilar tip. *Neuroradiol J* 2019; 32: 193-199.
- [22] Keskin F, Erdi F, Kaya B, Poyraz N, Keskin S, Kalkan E, Ozbek O and Koc O. Endovascular treatment of complex intracranial aneurysms by pipeline flow-diverter embolization device: a single-center experience. *Neurol Res* 2015; 37: 359-365.
- [23] Kitahara T, Hatano T, Hayase M, Hattori E, Miyakoshi A and Nakamura T. Jailed double-microcatheter technique following horizontal stenting for coil embolization of intracranial wide-necked bifurcation aneurysms: a technical report of two cases. *Interv Neuroradiol* 2017; 23: 117-122.
- [24] Kim TG, Kim SH, Cho KG and Chung SS. Endovascular treatment of internal carotid-posterior communicating artery wide-necked aneurysm using 2 Enterprise stents in Y-configuration. *Clin Neurol Neurosurg* 2013; 115: 1117-1120.
- [25] Khatri R, Cordina SM, Hassan AE, Grigoryan M and Rodriguez GJ. Sequential sidelong balloon remodeling technique in coil embolization of a wide-necked basilar tip aneurysm. *J Vasc Interv Neurol* 2013; 6: 7-9.
- [26] Mountrakis L, Lorenz E and Hoekstra AG. Where do the platelets go? A simulation study of fully resolved blood flow through aneurysmal vessels. *Interface Focus* 2013; 3: 20120089.
- [27] Oran I, Cinar C, Bozkaya H and Beşir FH. The rapid pull-back technique for navigation across a wide-necked aneurysm. A report of four cases. *Interv Neuroradiol* 2013; 19: 16-20.
- [28] Rong-Bo Q, Hua J, Kai W and Ze-Lin S. Stent-jail technique in endovascular treatment of wide-necked aneurysm. *Turk Neurosurg* 2013; 23: 179-182.
- [29] Qi L and Jinlu Y. Moyamoya disease with posterior communicating artery aneurysm: a case report. *Turk Neurosurg* 2013; 23: 546-550.