Turk Neurosurg, 2022

Original Investigation

DOI: 10.5137/1019-5149.JTN.37008-21.2

Received: 18.11.2021
Accepted: 28.02.2022

Published Online: 20.07.2022

Effect of Pathogenesis-Based Individualized Thrombectomy on Treatment Result and Prognosis of Acute Intracranial Large-Artery Occlusion Patients

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ABSTRACT

AIM: To explore the effect of pathogenesis-based individualised thrombectomy on the clinical results and prognoses of acute intracranial large-artery occlusion.

MATERIAL and METHODS: A total of 151 patients were included in this prospective study and divided into the control group (stent thrombectomy, 53 cases), a direct aspiration first pass technique (ADAPT) group (52 cases) and the stent group (stent thrombectomy or a combination of stent thrombectomy and ADAPT, 46 cases) based on whether stent or ADAPT was used. We compared and analysed the patients' general information, the National Institutes of Health Stroke Scale (NHISS) score at admission, the time between the end of arteriography and revascularisation, the number of thrombectomies, the modified Rankin scale (mRS) score at three months and complications in the three groups.

RESULTS: Compared with the control group, the time between the end of arteriography and revascularisation in the ADAPT group was significantly reduced (p<0.05), and the patency rate after one thrombectomy significantly increased (p<0.05). The positive prognosis rate was significantly increased in the stent and ADAPT groups compared with the control group (p<0.05).

CONCLUSION: The application of the ADAPT technique in patients with embolism-induced cerebral infarction can reduce the time of revascularisation. The use of stents in patients with atherosclerosis-induced cerebral infarction can increase the patency rate after one thrombectomy.

KEYWORDS: Arterial Occlusive Diseases, Pathogenesis, Thrombectomy, Stent

INTRODUCTION

Acute cerebral infarction caused by intracranial large-artery occlusion, characterised by high morbidity, high disability rates and high mortality, may lead to fatal ischemic and hypoxic damage to brain tissues and nerve cells in a short time; therefore, early and efficient revascularisation to restore cerebral blood flow is crucial for alleviating the injury in ischemic penumbra (7). Currently, intravenous thrombolysis is a widely used treatment method for acute ischemic stroke, but its short window time and low revascularisation rate in intracranial large-artery occlusion do not allow this method to achieve an ideal clinical effect (19). Mechanical thrombectomy, an interventional therapy for intracranial vessels, is superior to intravenous thrombolysis in terms of window time and revascularisation rates (16). The methods of mechanical thrombectomy include stent thrombectomy, a direct aspiration first pass technique (ADAPT) and a combination of stent and aspiration methods (Solumbra).

Stent has become one of the most important mechanical embolectomy methods for treating acute cerebral infarction.

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However, studies have pointed out the problems of single technical means and relatively low recanalisation rates remaining in the current mechanical thrombectomy (2,6). Although the clinical effect of a stent for cerebral infarction has been confirmed, one-third of patients still do not achieve recanalisation (11). Therefore, improving the recanalisation rate of occluded vessels has become the key to treating acute ischemic stroke (6,10). In recent years, the emergence of ADAPT has posed an alternative to a stent. ADAPT uses a larger diameter catheter, and the suction catheter does not pass through the thrombus part, which is close to the thrombus after negative pressure suction. It can more completely extract the intravascular embolus and improve the recanalisation rate. The technology of ADAPT is very simple. The operator usually does not have to traverse the block completely, and in most cases, there is no need to deploy or manipulate other equipment (17). ADAPT can easily remove large thrombi. But when a large thrombus is squeezed into a small thrombus, these small thrombi will block the distal small blood vessels along with blood flow, then causing distal coronary embolism, cerebral embolism, direct coronary artery injury, etc. Balloon dilatation followed by reaspiration or stent may be required to remove these small distal thrombi in this case.

Although ADAPT and stent are both safe and effective treatment methods for thrombectomy and revascularisation of the intracranial artery, which method is more suitable for acute cerebral infarction caused by different pathogeneses is not known yet, and research on this problem is still limited. So in this study, we investigated the effects of pathogenesis-based individualised thrombectomy on treatment results and prognoses of acute intracranial large-artery occlusion in order to provide suggestions for improving the treatment and prognosis.

MATERIAL and METHODS

Subjects

A total of 151 patients with acute cerebral infarction who underwent interventional therapy of the intracranial vessels in our hospital from January 2018 to November 2019 were included in this study. These 151 patients were divided into the control group (53 cases) and two experimental groups, the ADAPT group (52 cases) and the stent group (46 cases). The control group was treated with stent thrombectomy. In the two experimental groups, the ADAPT group was treated with a direct aspiration first pass technique and the stent group was treated with stent thrombectomy or a combination of stent thrombectomy and ADAPT.

The 2018 Chinese Guidelines for the Early Management of Patients With Acute Ischemic Stroke determined the inclusion and exclusion criteria of interventional therapy in intracranial vessels (14). The Ethics Committee of our hospital approved the current study, and all patients signed written informed consent.

The patients treated between January 2018 to December 2018 were the control group, and all were treated with stent thrombectomy. The patients treated between January 2019 to November 2019 were the experimental group, and the methods were selected according to their pathogeneses, medical histories, clinical manifestations and cerebral angiography results. The details are as follows. If patients had atrial fibrillation, the disease onset was very sudden and cerebral angiography showed a cup-like (flat head) shape in the occluded vessel and it was very likely to be embolism-induced cerebral infarction (Figure 1A). For these patients, ADAPT was used for thrombectomy (ADAPT group). If patients had a progressive stroke without atrial fibrillation and cerebral angiography showed a rabbit tail sign, it was more likely to be atherosclerosis-induced cerebral infarction (Figure 1B), and stent thrombectomy was used for these

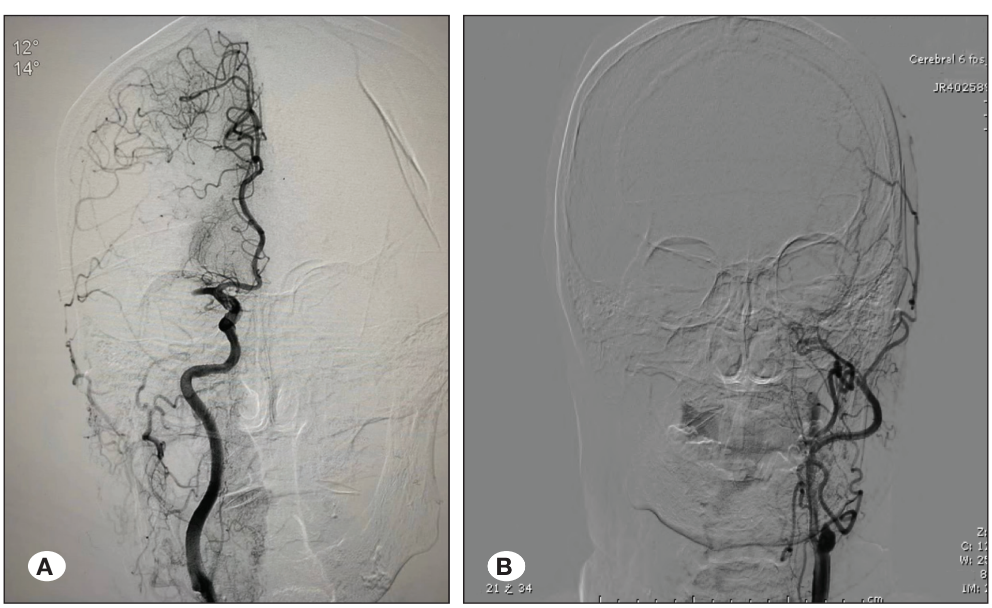

Figure 1: A) M1 occlusion of the middle cerebral artery cause by embolism. **B)** Occlusion of the initial segment of the internal carotid caused by atherosclerosis.

patients (stent group). The medical history, National Institutes of Health Stroke Scale (NHISS) score at admission, the time between the end of arteriography and revascularisation, the number of thrombectomies, the modified Rankin scale (mRS) score at three months and complications were collected and compared among the three groups.

Revascularisation of Occluded Vessels

Arteriography was performed to figure out the offending vessels and the compensation of those vessels, and interventional therapy was used in patients with good compensation for the offending vessels. The thrombectomy method was selected based on the arteriography results, whether haemadostenosis existed or not, as well as the pathogenesis (if a combination of stent and aspiration method was used, the patients were categorised into the stent group). If the first thrombectomy was unsuccessful, a second thrombectomy or balloon dilatation was then performed to revascularise the occluded vessels. After the vessels were opened, their blood flow was monitored for 20 minutes to evaluate the risk of reblocking. For reblocking in those who had in situ haemadostenosis, balloon dilatation or stent angioplasty was also performed during the first thrombectomy.

Surgical Operation

An experienced doctor performed all operations.

A direct aspiration first pass technique technology

1) The drape was routinely sterilised after general anaesthesia, an 8F vascular sheath was first inserted after successful right femoral artery puncture and cerebral artery angiography was performed to identify the location of the vascular occlusion. 2) Then a 6F Neuron MAX catheter was inserted under the guidance of the loach guide ribbon lining tube to the vicinity of the vascular occlusion using the Synchro microguide wire microcatheter ACE thrombus aspiration catheter coaxial technology under the path diagram to guide the ACE thrombus aspiration catheter to the vascular occlusion site, and the aspiration catheter was connected directly to the negative penumbra after accurate positioning. After pressing the suction pump, there was no blood flow in the suction system, which proved to be combined with thrombus. At this time, the catheter was gently pushed 1 to 2 mm to ensure a firm connection with the thrombus. 3) Vacuum suction was continued for 90 s. If there was no blood flow through the system, the ACE suction was slowly taken out while maintaining negative pressure suction. The catheter was suctioned until the blood flow rate in the negative pressure pump connection tube returned to normal. It could be pumped multiple times (the procedure was similar each time). If the blood vessel could not be recanalised or the thrombus escaped after three times, the Solitaire fr stent suction catheter (diameter 4 mm, length 20 mm) was released for remedy.

Stent technology

1) After general anaesthesia, the drape was routinely sterilised, the right femoral artery puncture was performed first by inserting a 6F vascular sheath, and cerebral artery angiography was performed to identify the location of the vascular occlusion. 2) Then, the loach guidewire was used to guide the 6F guide catheter to the vicinity of the vascular occlusion. Under the path diagram, the Synchro microguide ribbon microcatheter was used to smoothly pass through the vascular occlusion site. The microcatheter angiography showed that the distal blood vessel was unobstructed. The Solitaire stent was chosen to accurately locate the occlusion segment and open it. 3) It was slowly pulled out after five minutes of observation. The stent was used for thrombus removal, and the final re-examination was performed. If the blood vessel failed to pass or the thrombus escaped, the above operation could be repeated.

Observation Indicators and Standards

Evaluation of the revascularisation of occluded vessels

The leading observation indicators were the occluded vessel recanalisation rates. The thrombolysis in cerebral infarction (TICI) reperfusion score was used to evaluate the revascularisation of occluded vessels and their reperfusion after mechanical thrombectomy. A score of 0 means no reperfusion, and there is no forward flow in the distal end of the occluded vessel. A score of 1 indicates small reperfusion, and the contrast agent could go through the occluded vessels but cannot fill their distal end. A score of 2 means partial reperfusion, and the contrast agent can fill the distal end of the occluded vessels at a low speed. A score of 2a means < two-thirds of the distal end of the occluded vessels were filled, and 2b means the distal end was completely filled at a rate lower than normal. A score of 3 means the distal end was completely filled at a normal speed. Scores of 2b and 3 were considered successful revascularisation of occluded vessels. The secondary observation indicators were the time between the end of arteriography and revascularisation, the patency rate after one thrombectomy and the revascularisation rates.

Evaluation of neurological function after stroke

The mRS is used to measure the neurological recovery of patients after stroke. The mRS is a 0 to 5 point scale: 0 = no symptoms, although slight symptoms may be present, and the patient is not aware of any new functional limitations and symptoms since the stroke; 1 = no significant disability despite symptoms and can carry out all usual duties and activities; 2 = slight disability and unable to carry out previous activities, but able to look after own affairs without assistance; 3 = moderate disability and requires some help but can walk without assistance; 4 = moderately severe disability and unable to walk and attend to own bodily needs without assistance; 5 = severe disability, bedridden, incontinent and requiring constant nursing care and attention, although there is no need for trained nurses several times during the day and night (4,21). If the mRS of patients three months after discharge was greater than three points, they are considered to have a positive prognosis. The number of patients with positive prognoses in each group was counted as the positive prognosis rate.

Statistical Analysis

SPSS 20.0 was used for statistical analysis. A rank sum test was used to analyse the data that were not normally distributed. Categorical data were analysed by the chi-square test. P<0.05 was considered statistically significant.

RESULTS

Baseline Data

As shown in Table I, there was no significant difference in gender, age, complications, pathogenesis, offending vessels and NHISS score at admission among the three groups (p>0.05).

Prognosis of the Patients

As shown in Table II, the time between the end of arteriography and revascularisation among the three groups was significantly different (p<0.01). There was no significant difference in the time between the end of arteriography and revascularisation between the control and stent groups (z=1.540, p>0.05) and between the stent and ADAPT groups (z=0.869, p>0.05). But compared with the control group, the time between the end of arteriography and revascularisation of the ADAPT group was significantly reduced (z=5.49, p<0.01).

The patency rate after one thrombectomy among the three groups was significantly different (p<0.05). There was no significant difference in patency rate after one thrombectomy between the control and ADAPT groups (c^2=2.162, p>0.05), and between the stent and ADAPT groups (c^2=1.052, p>0.05). But compared with the control group, the patency rate after one thrombectomy of the stent group significantly increased (c^2=5.910, p<0.05).

There was no significant difference in the revascularisation rates among the three groups (p>0.05). The positive prognosis rates were significantly different among the three groups (p<0.05), and compared with the control group, the positive prognosis rates of the two experimental groups obviously increased.

DISCUSSION

The leading causes of occlusion-induced cerebral infarction are atherosclerosis and cardioembolism, as well as other causes. It has been reported that in China, atherosclerosis-induced cerebral infarction accounts for 46.6% of all cases; therefore, atherosclerosis is considered to be the most common vasculopathy in patients with cerebral infarction

Table I: Baseline Data

			Complicating diseases			Pathogenesis		Offending vessels		
Group (n)	**Gender (male/ female)**	**Age [average (min, max)]**	**Hypertension (yes/no)**	**Diabetes mellitus (yes/no)**	**Atrial fibrillation (yes/no)**	**Embolism**	**Non-embolism**	**Internal carotid system**	**Vertebrobasilar system**	**NHISS score at admission**
Control group (53)	32/21	66 (61,73)	32/21	14/39	17/36	33	20	45	8	19 (15,22)
Stent group (46)	32/14	65 (59,71)	35/11	13/33	35/63	52	46	38	8	17 (14,22)
ADAPT group (52)	33/19	63 (58,72)	36/16	20/32				34	18	20 (15,22)
	c^2=926	Z=1.59	c^2=2.841	c^2=2.030	c^2=0.202	c^2=1.184		c^2=4.434		c^2=9.74
p	0.629	0.125	0.242	0.362	0.653	0.227		0.109		0.226

Table II: Prognosis of the Patients

Group (n)	**The time between the end of arteriography and revascularization (minutes) [average (min, max)]**	**Patency rate after one thrombectomy**	**Revascularization rate**	**MRS score at 3 month < 3**
Control group (53)	57 (37,67)	24/53	50/53	35/53
Stent group (46)	36 (30,50)	32/46	44/46	39/46
ADAPT group (52)	39 (24,58)	31/52	51/52	44/52
	c^2=12.96	c^2=6.076	c^2=6.076	c^2=7.011 0.001 0.982
p	0.002	0.048	0.611	0.03

in China (20). Atherosclerosis-induced cerebral infarction is mainly caused by in situ thrombi in the haemadostenosis vessel (13). In 2014, Turk et al. (17) reported that the success rate of ADAPT was 75%, and 65% of the patients reached a TICI reperfusion score of 3, with an average revascularisation time of 28.1 minutes, and the fastest one was 3 minutes. A recent systematic retrospective study (15), which included 9,127 patients who underwent mechanical thrombectomy of the intracranial artery, showed positive results (52% vs 48%), and the three-month mortality (15% vs 19%) of ADAPT and stent were similar. The COMPASS study also showed that patients' improvement functions after ADAPT and stent were similar (18).

The thrombi of atherosclerosis-induced cerebral infarctions are mostly white thrombi composed of platelets and fibrin. These thrombi stick tightly to the inner walls of the blood vessels, and artery stenosis is also common. Therefore, it is difficult for the suction catheter to completely contact and remove the thrombi. The ADAPT is not suitable for eliminating thrombi in atherosclerotic cerebral infarctions; thus, a stent is needed (8). However, the thrombi of cardioembolism-induced cerebral infarctions are mostly red thrombi composed of red blood cells, which bind loosely to the inner walls of the blood vessels, and the suction catheter can reach the embolisms and take them out. So ADAPT is more effective for removing the thrombi of cardioembolism-induced cerebral infarctions, which has also been verified by research (5). Therefore, both ADAPT and stent are safe and effective treatment methods in thrombectomy and revascularisation of the intracranial artery.

Previous research reported (22) that only 15 out of 29 patients with internal carotid artery occlusions were found to have thrombi in the retrieved stent after thrombectomy, and no thrombi were found in other patients, even after multiple stent thrombectomies, which proves that thrombi are not often found in this type of cerebral infarction. In another study (9), it was found that with acute intracranial artery occlusion caused by internal carotid atherosclerosis, stent thrombectomy was better than ADAPT in the time between the end of arteriography and revascularisation and the duration of the operation; thus, it was concluded that stent thrombectomy was better than ADAPT in this type of intracranial artery occlusion. On the contrary, for embolism-induced cerebral infarction, researchers believe that ADAPT might be better than stent thrombectomy (1). In the current study, we found that the time between the end of arteriography and revascularisation was significantly shorter in the ADAPT group than in the control group, which proves that ADAPT may be a better choice for embolism-induced cerebral infarction.

With the development of suction catheter materials, ADAPT has improved from the initial direct contact with the thrombus to the current negative pressure suction technique, which partially contacts the thrombi and the suction catheter can also be left in the vessel for the second angiography and thrombectomy (1). It was reported in a recent study that the success rate of ADAPT was related to its angle toward the thrombus, and when the angle was ≥125.5°, the success rate increased significantly, especially in the middle cerebral and basilar arteries (3). For thrombosis based on haemadostenosis, the vessels are in a cone-shape, making the vascular wall irregular; thus, the suction catheter cannot contact the thrombus at an adequate angle, so a stent is a better choice because it can pass the hemadostenosis area and pull the thrombus outside the vessel. In addition, in such circumstances, a stent angioplasty is performed simultaneously, which can instantly restore the forward flow and shorten the revascularisation time. Thrombolysis can also partially be achieved by the plasminogen ability of the blood that goes through the revascularised vessel. In this study, the patency rate after one thrombectomy was significantly higher in the stent group than in the other two groups, confirming this theory.

In this study, the time of the stent group was longer than the ADAPT group, but the positive prognosis rate of the two groups was similar, which could be due to the fact that for atherosclerosis-induced cerebral infarction, a longer time is needed to completely occlude the vessel; thus the fractional collateral flow was better than embolism-induced cerebral infarction (12).

Several limitations should be taken into consideration. This study was a single-centre study, and the sample size was not large enough to draw a more appropriate predetermined treatment algorithm used in the management of the patients' cohort. So we need more cases to analyse the effects of thrombectomy methods, pathogeneses and complicating diseases. And we also need to perform multi-centre and large-sample clinical trials to evaluate the positive prognosis rates after mechanical thrombectomy to establish an individualised thrombectomy method that can better treat cerebral infarction.

CONCLUSION

The application of the ADAPT technique in patients with embolism-induced cerebral infarction can reduce the time of revascularisation. The use of stents in patients with atherosclerosis-induced cerebral infarctions can increase the patency rate after one thrombectomy. An adequate thrombectomy method based on pathogeneses can increase the positive prognoses rate in patients with acute intracranial large-artery occlusions.

AUTHORSHIP CONTRIBUTION

Study conception and design: YCL

Data collection: MMZ

Analysis and interpretation of results: YCL, SWX

Statistical analysis: QRL

Writing of the manuscript: YCL, JYW

Critical revision of the article: YCL, MMZ, YL, SWX, QRL, JYW

All authors (YCL, MMZ, YL, SWX, QRL, JYW) reviewed the results and approved the final version of the manuscript.

REFERENCES

1. Alawieh A, Chatterjee AR, Vargas J, Chaudry MI, Lena J, Turner R, Turk A, Spiotta A: Lessons learned over more than 500 stroke thrombectomies using ADAPT with increasing aspiration catheter size. Neurosurgery 86(1):61-70, 2020
2. Berkhemer OA, Fransen PS, Beumer D, van den Berg LA, Lingsma HF, Yoo AJ, Schonewille WJ, Vos JA, Nederkoorn PJ, Wermer MJH, van Walderveen MAA, Staals J, Hofmeijer J, van Oostayen JA, Lycklama à Nijeholt GJ, Boiten J, Brouwer PA, Emmer BJ, de Bruijn SF, van Dijk LC, Kappelle LJ, Lo RH, van Dijk EJ, de Vries J, de Kort PLM, van Rooij WJJ, van den Berg JSP, van Hasselt BAAM, Aerden LAM, Dallinga RJ, Visser MC, Bot JCJ, Vroomen PC, Eshghi O, Schreuder THCML, Heijboer RJJ, Keizer K, Tielbeek AV, den Hertog HM, Gerrits DG, van den Berg-Vos RM, Karas GB, Steyerberg EW, Flach HZ, Marquering HA, Sprengers MES, Jenniskens SFM, Beenen LFM, den Berg RV, Koudstaal PJ, van Zwam WH, Roos YBWEM, van der Lugt A, van Oostenbrugge RJ, Majoie CBLM, Dippel DWJ, CLEAN Investigators MR. A randomized trial of intra arterial treatment for acute ischemic stroke. N Engl J Med 372(1):11-20, 2015
3. Bernava G, Rosi A, Boto J, Brina O, Kulcsar Z, Czarnetzki C, Carrera E, Schaller K, Lovblad K, Machi P: Direct thromboaspiration efficacy for mechanical thrombectomy is related to the angle of interaction between the aspiration catheter and the clot. J Neurointerv Surg 12(4):396-400, 2020
4. Cohen J: Interrater reliability and predictive validity of the FOUR score coma scale in a pediatric population. J Neurosci Nurs 41(5):261-267; quiz 268-269, 2009
5. Gory B, Armoiry X, Sivan-Hoffmann R, Piotin M, Mazighi M, Lapergue B, Blanc R, Turjman F: A direct aspiration first pass technique for acute stroke therapy: A systematic review and meta-analysis. Eur J Neurol 25(2):284-292, 2018
6. Goyal M, Demchuk AM, Menon BK, Eesa M, Rempel JL, Thornton J, Roy D, Jovin TG, Willinsky RA, Sapkota BL, Dowlatshahi D, Frei DF, Kamal NR, Montanera WJ, Poppe AY, Ryckborst KJ, Silver FL, Shuaib A, Tampieri D, Williams D, Bang OY, Baxter BW, Burns PA, Choe H, Heo JH, Holmstedt CA, Jankowitz B, Kelly M, Linares G, Mandzia JL, Shankar J, Sohn S, Swartz RH, Barber PA, Coutts SB, Smith EE, Morrish WF, Weill A, Subramaniam S, Mitha AP, Wong JH, Lowerison MW, Sajobi TT, Hill MD, ESCAPE Trial Investigators: Randomized assessment of rapid endovascular treatment of ischemic stroke. N Engl J Med 372(11):1019-1030, 2015
7. Goyal M, Menon BK, Van ZwamWH, Dippel DWJ, Mitchell PJ, Demchuk AM, Dávalos A, Majoie CBLM, der Lugt AV, de Miquel MA, Donnan GA, Roos YBWEM, Bonafe A, Jahan R, Diener H, den Berg LAV, Levy EI, Berkhemer OA, Pereira VM, Rempel J, Millán M, Davis SM, Roy D, Thornton J, Román LS, Ribó M, Beumer D, Stouch B, Brown S, Campbell BCV, van Oostenbrugge RJ, Saver JL, Hill MD, Jovin TG, HERMES collaborators: Endovascular thrombectomy after large-vessel ischaemic stroke: A meta-analysis of individual patient data from five randomised trials. Lancet 387(10029):1723-1731, 2016
8. Kang DH, Kim YW, Hwang YH, Park SP, Kim YS, Baik SK: Instant reocclusion following mechanical thrombectomy of in situ thromboocclusion and the role of low-dose intra-arterial tirofiban. Cerebrovasc Dis 37(5):350-355, 2014
9. Kang DH, Yoon W: Current opinion on endovascular therapy for emergent large vessel occlusion due to underlying intracranial atherosclerotic stenosis. Korean J Radiol 20(5): 739-748, 2019
10. Khatri P, Yeatts SD, Mazighi M, Broderick JP, Liebeskind DS, Demchuk AM, Amarenco P, Carrozzella J, Spilker J, Foster LD, Goyal M, Hill MD, Palesch YY, Jauch EC, Haley EC, Vagal A, Tomsick TA, IMS III Trialists. Time to angiographic reperfusion and clinical outcome after acute ischaemic stroke: an analysis of data from the Interventional Management of Stroke (IMS III) phase 3 trial. Lancet Neurol 13(6):567-574, 2014
11. Kidwell CS, Jahan R: Endovascular treatment of acute ischemic stroke. Neurol Clin 33(2):401-420, 2015
12. Kim SJ, Ryoo S, Kim GM, Chung CS, Lee KH, Bang OY: Clinical and radiological outcomes after intracranial atherosclerotic stroke: A comprehensive approach comparing stroke subtypes. Cerebrovasc Dis 31:427-434, 2011
13. Lee JS, Hong JM, Kim JS: Diagnostic and therapeutic strategies for acute intracranial atherosclerosis-related occlusions. J Stroke 19:143-151, 2017
14. Martin K, Beyer-Westendorf J, Davidson BL, Huisman MV, Sandset PM, Moll S: Use of the direct oral anticoagulants in obese patients: Guidance from the SSC of the ISTH. J Thromb Haemost 14(6):1308-1313, 2016
15. Primiani CT, Vicente AC, Brannick MT, Turk AS, Mocco J, Levy EI, Siddiqui AH, Mokin M: Direct aspiration versus stent retriever thrombectomy for acute stroke: A systematic review and meta-analysis in 9127 patients. J Stroke Cerebrovasc Dis 28(5):1329-1337, 2019
16. Saver JL, Goyal M, Bonafe A, Diener HC, Levy EI, Pereira VM, Albers GW, Cognard C, Cohen DJ, Hacke W, Jansen O, Jovin TG, Mattle HP, Nogueira RG, Siddiqui AH, Yavagal DR, Baxter BW, Devlin TG, Lopes DK, Reddy VK, de Rochemont RDM, Singer OC, Jahan R, SWIFT PRIME Investigators: Stent-retriever thrombectomy after intravenous t-PA vs. t-PA alone in stroke. N Engl J Med 372(24):2285-2295, 2015
17. Turk AS, Frei D, Fiorella D, Mocco J, Baxter B, Siddiqui A, Spiotta A, Mokin M, Dewan M, Quarfordt S, Battenhouse H, Turner R, Chaudry I: ADAPT FAST study: A direct aspiration first pass technique for acute stroke thrombectomy. J Neurointerv Surg 6(4):260-264, 2014
18. Turk AS 3rd, Siddiqui A, Fifi JT, Leacy RA, Fiorella DJ, Gu E, Levy EI, Snyder KV, Hanel RA, Aghaebrahim A, Woodward BK, Hixson HR, Chaudry MI, Spiotta AM, Rai AT, Frei D, Delgado Almandoz JE, Kelly M, Arthur A, Baxter B, English J, Linfante I, Fargen KM, Mocco J: Aspiration thrombectomy versus stent retriever thrombectomy as first-line approach for large vessel occlusion (COMPASS): A multicentre, randomised, open label, blinded outcome, non-inferiority trial. Lancet 393(10175): 998-1008, 2019
19. Vargas J, Spiotta AM, Fargen K, Turner RD, Chaudry I, Turk A: Experience with a direct aspiration first pass technique (ADAPT) for thrombectomy in distal cerebral artery occlusions causing acute ischemic stroke. World Neurosurg 9:31-36, 2017

20. Wang Y, Zhao X, Liu L, Soo YOY, Pu YH, Pan YS,Wang YL, Zou XY, Leung TWH, Cai YF, Bai QK, Wu YP, Wang CX, Pan XP, Luo BY, Wong KSL, CICAS Study Group: Prevalence and outcomes of symptomatic intracranial large artery stenoses and occlusions in China: The Chinese Intracranial Atherosclerosis (CICAS) study. Stroke 45:663-669, 2014
21. Wu D, Wu L, Chen J, Huber M, He X, Li S, Ding Y, Ji X: Primate version of modified rankin scale for classifying dysfunction in rhesus monkeys. Stroke 51(5):1620-1623, 2020
22. Yoon W, Kim SK, Park MS, Kim BC, Kang HK: Endovascular treatment and the outcomes of atherosclerotic intracranial stenosis in patients with hyperacute stroke. Neurosurgery 76: 680-686, 2015