









Predictors of a Favorable Outcome after Emergent Carotid Artery Stenting in Acute Anterior Circulation Stroke Patients

급성 전방순환 뇌경색 환자에서 응급 경동맥 스텐트 삽입술 후 양호한 임상 결과의 예측인자

Gyeong Il Moon, MD¹ , Byung Hyun Baek, MD¹ , Seul Kee Kim, MD² ,
 Yun Young Lee, MD¹ , Hyo-Jae Lee, MD¹ , Woong Yoon, MD^{1*} 

¹Department of Radiology, Chonnam National University Medical School, Gwangju, Korea
²Department of Radiology, Chonnam National University Hwasun Hospital, Hwasun, Korea

Purpose This study aimed to identify independent predictors of favorable outcomes associated with emergent carotid artery stenting (CAS) in patients with acute anterior circulation stroke.

Materials and Methods This study included 93 patients with acute stroke who underwent emergent CAS to treat stenocclusive lesions in the cervical internal carotid artery (ICA) within 6 hours of the onset of the associated symptoms. Data were compared between patients with and without favorable outcomes. The independent predictors of a favorable outcome were determined via logistic regression analysis (modified Rankin Scale 0–2 at 90 days).

Results Intracranial tandem occlusion was noted in 81.7% of patients (76/93) among which (76/93), 55 of whom underwent intracranial recanalization therapy. Intracranial reperfusion was successful in 74.2% (69/93) and favorable outcomes were noted in 51.6% of patients (48/93). The mortality rate was 6.5% (6/93). In logistic regression analysis, diffusion-weighted imaging-Alberta Stroke Program Early CT Score [odds ratio (OR), 1.487; 95% confidence interval (CI), 1.018–2.173, $p = 0.04$], successful reperfusion (OR, 5.199; 95% CI, 1.566–17.265, $p = 0.007$), and parenchymal hemorrhage (OR, 0.042; 95% CI, 0.003–0.522, $p = 0.014$) were independently associated with a favorable outcome.

Conclusion Baseline infarct size, reperfusion status, and parenchymal hemorrhage were independent predictors of favorable outcomes after emergent CAS to treat stenocclusive lesions in the cervical ICA in patients with acute anterior circulation stroke.

Index terms Carotid Artery Stenting; Acute Stroke; Thrombectomy; Prognosis







Received June 27, 2019
 Revised August 9, 2019
 Accepted September 14, 2019

*Corresponding author
 Woong Yoon, MD
 Department of Radiology,
 Chonnam National
 University Hospital,
 Chonnam National University
 Medical School, 42 Jebong-ro,
 Dong-gu, Gwangju 61469, Korea.

Tel 82-62-220-5746
 Fax 82-62-226-4380
 E-mail radyoon@jnu.ac.kr

This is an Open Access article distributed under the terms of the Creative Commons Attribution Non-Commercial License (<https://creativecommons.org/licenses/by-nc/4.0>) which permits unrestricted non-commercial use, distribution, and reproduction in any medium, provided the original work is properly cited.

ORCID iDs

Gyeong Il Moon 
<https://orcid.org/0000-0002-9984-0370>
 Byung Hyun Baek 
<https://orcid.org/0000-0002-8657-1052>
 Seul Kee Kim 
<https://orcid.org/0000-0002-1508-5057>
 Yun Young Lee 
<https://orcid.org/0000-0002-1200-9462>
 Hyo-Jae Lee 
<https://orcid.org/0000-0001-7770-6800>
 Woong Yoon 
<https://orcid.org/0000-0002-8598-3127>

INTRODUCTION

The clinical course of cervical internal carotid artery (ICA) occlusion varies from asymptomatic to devastating stroke depending on collateral status and presence or absence of tandem occlusion of intracranial arteries (1-3). It has been reported that cervical ICA stenooclusive lesions could be detected in 13–29% of patients with acute anterior circulation stroke (4-7). Acute stroke attributable to tandem extracranial and intracranial occlusions is usually associated with the risk of major stroke and poor clinical outcomes (1-3, 8, 9). However, the optimal treatment strategy for patients with acute ischemic stroke (AIS) caused by occlusion or high-grade stenosis of cervical ICA has not been established yet (10, 11).

Intravenous thrombolysis using recombinant tissue plasminogen activator (r-tPA) has been associated with poor response in patients with cervical ICA occlusion with respect to recanalization and clinical outcome (12-16). Emergent carotid artery stenting (CAS) for acute stenooclusive lesions in the cervical ICA improve intracranial perfusion, prevent further artery-to-artery embolism, and decrease long-term recurrent stroke rate. Previous studies reported feasibility and efficacy of endovascular therapy for acute stroke due to cervical ICA occlusion, such as emergent CAS with or without concomitant intracranial reperfusion therapy (17-27). However, prognostic factors for clinical outcome after emergent CAS in acute stroke patients with cervical ICA stenooclusive lesion have not been adequately investigated to date. Therefore, the aim of this study was to evaluate clinical outcomes and to investigate independent predictors for favorable outcome after emergent CAS in patients with acute stroke caused by occlusion or high-grade stenosis of cervical ICA.

MATERIALS AND METHODS

PATIENTS

From July 2007 to June 2017, a total of 93 consecutive patients who presented with AIS due to atherosclerotic occlusion or high-grade stenosis of the cervical ICA underwent emergent CAS with or without intracranial reperfusion therapy. The clinical and radiologic data from these 93 patients were prospectively collected into our stroke database and retrospectively analyzed. On admission, neurologic assessment based on the National Institutes of Health Stroke Scale (NIHSS) was performed by a stroke neurologist. All patients underwent an initial imaging protocol including nonenhanced brain CT scan and multimodal MR imaging before endovascular therapy. MR imaging examinations were performed using a 1.5-T unit (Signa HDxt; GE Medical Systems, Milwaukee, WI, USA). Multimodal MR imaging sequence included diffusion-weighted imaging, gradient echo imaging, fluid attenuation inversion recovery sequence, and 3-dimensional time-of-flight MR angiography. This study was approved by the Institutional Review Board, and requirements for informed consent were waived on the basis of the study design (IRB No. CNUH-2017-054).

ENDOVASCULAR TREATMENT

The inclusion criteria for endovascular therapy were as follows: 1) femoral artery puncture started within 6 hours of symptom onset, 2) no intracranial hemorrhage detected on brain

CT or MR imaging, 3) infarct volume on diffusion-weighted image (DWI) or nonenhanced CT less than one-third of middle cerebral artery (MCA) territory, and 4) angiographically proven complete occlusion or high grade (> 90%) stenosis with distal flow limitation in the cervical ICA. Cervical ICA steno-occlusive lesion was classified into atherosclerotic disease or dissection. Atherosclerotic steno-occlusion was determined when the lesion was present in the ICA bulb, involved short segment, and ICA segment distal to the lesion was patent on catheter angiogram. Dissection was defined when a false lumen or an intimal flap was detected on catheter angiogram (27). Eligible patients received intravenous r-tPA before endovascular therapy.

All endovascular procedures were conducted under local anesthesia. After passage of a microcatheter through the carotid stenocclusive lesion, microcatheter injection was performed to assess intracranial circulation. Then, a distal embolic protection device (Emboshield Nav6, Abbott Vascular, Santa Clara, CA, USA or SpiderRX, ev3, Inc, MN, USA) was deployed in the distal cervical ICA. Pre-stenting angioplasty was performed with a balloon catheter (Sterling, Boston Scientific, Marlborough, MA, USA) with a diameter of 5 or 6 mm. After angioplasty, CAS was performed using a RX Acculink carotid stent (Abbott Vascular). Post-stent balloon dilatation was limitedly performed when residual stenosis was greater than 50% according to the North American Symptomatic Carotid Endarterectomy Trial criteria (28). For intracranial reperfusion, mechanical thrombectomy using a stent-retriever was primarily used. Additional clot aspiration thrombectomy using an intermediate catheter were performed when stent retriever thrombectomy failed. In the early study period, intra-arterial urokinase infusion was performed as an intracranial reperfusion therapy. In patients with tandem occlusions, all intracranial reperfusion therapy was performed after performing emergent CAS. The details of the techniques about mechanical thrombectomy were previously described (29). Immediate post-treatment nonenhanced CT was performed in all patients. If post-treatment CT showed no intracranial hemorrhage, aspirin (100 mg/d) and clopidogrel (75 mg/d) were administered through nasogastric tube. The dual antiplatelet regimen continued for at least 3 months after procedure. Glycoprotein IIb/IIIa inhibitor was not given during or after the procedure. Follow-up neck and brain CT angiography was performed before discharge, if the patient's condition permitted.

OUTCOME MEASURES

DWI-Alberta Stroke Program Early CT score (ASPECTS) was assessed on pretreatment DWI by two neuroradiologists who were blinded to clinical information. Conclusions were reached by consensus. The 'time to procedure' was defined as the time from symptom onset to groin puncture. The 'procedure time' was defined as the time from groin puncture to final angiogram. And the 'time to reperfusion' was defined as the time from symptom onset to final angiogram. Intracranial reperfusion status was assessed on final angiogram according to modified Treatment In Cerebral Ischemia (m-TICI) scale (30). The successful reperfusion was defined as an m-TICI grade of 2b or 3. Post-treatment intracranial hemorrhage was assessed on a nonenhanced CT or gradient echo MR images. Hemorrhagic transformation was classified as hemorrhagic infarction or parenchymal hemorrhage based on the European Cooperative Acute Stroke Study II criteria (31). Symptomatic hemorrhage was defined as any intracranial hemor-

rhage that caused neurological deterioration (≥ 4 points increase in the NIHSS score or a deterioration of 1 point in the level of consciousness on NIHSS). Clinical outcome was evaluated by stroke neurologists by using a modified Rankin Scale (mRS) score after 3 months during outpatient visit. If patients were unable to visit, outcomes were obtained via telephone interview. A favorable clinical outcome was defined as an mRS score of 0–2.

STATISTICAL ANALYSIS

Continuous variables are presented as medians and interquartile ranges. Categorical variables are presented as numbers and percentages. First, clinical and procedural characteristics were compared between patients with favorable outcome and those with unfavorable outcome. The χ^2 test or Fisher exact test was used for categorical variables as appropriate. The Mann-Whitney U test was used for continuous variables. Second, binary logistic regression analysis was performed to determine independent predictors of favorable outcome. The inclusion cutoff value for variables tested in the binary logistic regression analysis was $p < 0.05$ in a univariate analysis. A significance was determined as p value of < 0.05 . All statistical analyses were performed with SPSS software (Version 21.0; IBM Corp., Armonk, NY, USA).

RESULTS

Ninety-three patients underwent emergent CAS within 6 hours of AIS onset. The median age was 72 years, ranging from 47 to 92 years. The median baseline NIHSS score on admission was 11, ranging from 6 to 19. Fifty-four patients (58.1%) received intravenous r-tPA before endovascular therapy. Seventy-six patients (81.7%) had a tandem intracranial occlusion: intracranial ICA in 15 patients, M1 segment of MCA in 39, M2 segment of MCA in 18, M3 segment of MCA in 4. Eight patients had concomitant anterior cerebral artery occlusion.

Overall, intracranial successful reperfusion was achieved in 74.2% (69/93) of patients. Underlying intracranial stenosis was found in 3 of 93 patients (3.2%) and these patients were treated with intracranial angioplasty. Procedural complications occurred in 5 patients (5.4%). Four patients had an embolization to new territories. Carotid cavernous fistula developed in one patient after balloon angioplasty. The procedure was terminated prematurely and the final m-TICI score was 0. This patient eventually died on postprocedure day 3 due to massive hemispheric infarction. On post-treatment CT, subarachnoid hemorrhage was detected in 3 patients (3.2%). Eighty-four patients (90.3%) received antiplatelet medication after endovascular therapy. During hospitalization, parenchymal hemorrhage occurred in 8 patients (8.6%) and symptomatic hemorrhage in 6 (6.5%). Seventy-seven patients underwent follow-up neck CT angiography before discharge. The remaining 16 patients could not undergo neck CT angiography due to their poor health status. In-stent thrombosis occurred in 6 of 77 (7.8%) patients who underwent follow-up neck CT angiography. All of these 6 patients received dual antiplatelet medication after endovascular therapy and did not undergo secondary recanalization therapy for acute stent occlusion. At 3 months, favorable outcome was achieved in 51.6% of patients (48/93). The 90-day mortality rate was 6.5% (6/93).

Of 76 patients with tandem occlusions, 21 patients did not undergo intracranial recanalization therapy because of following reasons: achievement of successful intracranial reperfu-

sion after CAS ($n = 14$), failure to access to intracranial occlusive lesion ($n = 1$), termination of procedure due to intra-procedural complication ($n = 1$), or according to operator's discretion ($n = 5$). Of 55 patients who received intracranial reperfusion therapy, 44 patients received mechanical thrombectomy only, 7 patients received intraarterial urokinase infusion only, and 4 patients received both thrombectomy and urokinase infusion. DWI-ASPECTS was significantly lower in patients with tandem intracranial occlusion compared with those without it (median value 7 vs. 8, $p = 0.013$). For 55 patients who received intracranial reperfusion therapy, successful reperfusion was achieved in 70.9% (39/55) and favorable outcome in 45.5% (25/55). Successful reperfusion occurred more frequently in patients treated with mechanical thrombectomy compared with those treated with intraarterial urokinase only (77.1% vs. 28.6%, $p = 0.018$). The rate of favorable outcome was not different between the two groups (45.8% vs. 42.9%, $p = 1.000$).

Table 1 shows comparisons in baseline and procedural characteristics between the patients with favorable outcome and those with unfavorable outcome. Table 2 presents comparisons in treatment outcomes between the two groups. For the entire cohort, following variables was associated with a favorable outcome: age, baseline NIHSS score, DWI-ASPECTS, tandem intracranial occlusion, concomitant anterior cerebral artery occlusion, successful reperfusion, parenchymal hemorrhage and symptomatic hemorrhage in univariate analysis. For the patients who underwent follow-up CT angiography ($n = 77$), favorable outcome was less frequent in patients with in-stent thrombosis compared to those without it (0% vs. 55.2%, $p = 0.011$). In multivariate logistic regression analysis adjusted for potential confounders (age, baseline NIHSS, DWI-ASPECTS, tandem intracranial occlusion, successful reperfusion, and parenchymal hemorrhage) (Table 3), DWI-ASPECTS [odds ratio (OR), 1.487; 95% confidence interval (CI), 1.018–2.173, $p = 0.04$], successful reperfusion (OR, 5.199; 95% CI, 1.566–17.265, $p = 0.007$), and parenchymal hemorrhage (OR, 0.042; 95% CI, 0.003–0.522, $p = 0.014$) were independent predictors of a favorable outcome at 90 days.

DISCUSSION

In this retrospective single center study, we found that emergent CAS resulted in a high rate of 90-day favorable outcome (51.6%) and low rates of mortality (6.5%) and procedural complication (5.4%) in patients with acute stenooclusive lesion in the cervical ICA. There have been several studies dealing with emergent CAS and combined intracranial thrombectomy for treating acute stroke caused by cervical ICA occlusion (19-27). In previous studies, the rate of intracranial successful reperfusion was reported to be 52–79%, favorable clinical outcome rate 33–56%, and mortality rate 8–21%. The mortality rate (6.5%) of the present study was quite lower than that of previous studies, while the rate of favorable outcome was comparable to that of previous studies.

In the current study, pretreatment DWI-ASPECTS, successful intracranial reperfusion, and parenchymal hemorrhage were found to be independent predictors for favorable outcome after emergent CAS. This result confirms previous notion that the baseline infarct size, final reperfusion status, and hemorrhagic complications are major determinants of clinical outcome in patients with acute anterior circulation stroke. Few studies have investigated inde-

Table 1. Comparison of Baseline and Procedural Characteristics between Patients with and without Favorable Outcomes after Emergent Carotid Artery Stenting

	Favorable Outcome (<i>n</i> = 48)	Unfavorable Outcome (<i>n</i> = 45)	<i>p</i>
Age, years	70 (64–74)	74 (69–79)	0.014
Sex, male	43 (89.6)	38 (84.4)	0.460
Risk factors			
Hypertension	32 (66.7)	30 (66.7)	1.000
Diabetes mellitus	15 (31.3)	14 (31.1)	0.988
Dyslipidemia	24 (50.0)	17 (37.8)	0.235
Smoking	33 (68.8)	29 (64.4)	0.660
Atrial fibrillation	3 (6.3)	7 (15.6)	0.189
Coronary artery disease	5 (10.4)	4 (8.9)	1.000
Congestive heart failure	1 (2.1)	2 (4.4)	0.609
Previous stroke or TIA	11 (22.9)	8 (17.8)	0.539
Intravenous thrombolysis	29 (60.4)	25 (55.6)	0.635
Baseline NIHSS score	10 (6–14)	12 (9–16)	0.010
DWI-ASPECTS	8 (7–9)	7 (6–8)	0.002
Cervical ICA lesion type			
Stenosis	24 (50.0)	16 (35.6)	0.160
Occlusion	24 (50.0)	29 (64.4)	0.160
Tandem intracranial occlusion	34 (70.8)	42 (93.3)	0.007
ICA	5 (10.4)	10 (22.2)	0.122
MCA	29 (60.4)	32 (71.1)	0.278
Concomitant ACA	1 (2.1)	7 (15.6)	0.027
Underlying intracranial stenosis	1 (2.1)	2 (4.4)	0.609
Time to procedure, min	252 (191–305)	260 (210–330)	0.319
Procedure time, min	32 (24–46)	40 (28–51)	0.054
Time to reperfusion, min	281 (216–342)	298 (251–367)	0.180
Use of embolic protection device	31 (64.6)	27 (60)	0.648
Intracranial thrombectomy	22 (45.8)	26 (57.8)	0.249

Values are presented as *n* (%) or median (interquartile range).

ACA = anterior cerebral artery, ASPECTS = alberta stroke program early CT score, DWI = diffusion-weighted image, ICA = internal carotid artery, MCA = middle cerebral artery, NIHSS = National Institutes of Health Stroke Scale, TIA = transient ischemic attack

Table 2. Comparisons in Treatment Outcomes between Patients with and without Favorable Outcomes

	Favorable Outcome (<i>n</i> = 48)	Unfavorable Outcome (<i>n</i> = 45)	<i>p</i>
Successful reperfusion	42 (87.5)	27 (60.0)	0.002
Subarachnoid hemorrhage	0	3 (6.7)	0.109
Parenchymal hemorrhage	1 (2.1)	7 (15.6)	0.027
Symptomatic hemorrhage	0	6 (13.3)	0.011

Values are presented as *n* (%).

Table 3. Univariate and Multivariate Binary Logistic Regression Analysis for Predictors of a Favorable 90-Day Outcome

	Unadjusted OR (95% CI)	<i>p</i>	Adjusted OR (95% CI)	<i>p</i>
Age, per 1-year increase	0.950 (0.904–0.999)	0.044	-	-
Baseline NIHSS score, per 1-point increase	0.880 (0.796–0.972)	0.012	-	-
DWI-ASPECTS, per 1-point increase	1.631 (1.189–2.238)	0.002	1.487 (1.018–2.173)	0.040
Tandem intracranial occlusion	0.173 (0.046–0.654)	0.010	-	-
Successful reperfusion	4.667 (1.645–13.240)	0.004	5.199 (1.566–17.265)	0.007
Parenchymal hemorrhage	0.116 (0.014–0.980)	0.048	0.042 (0.003–0.522)	0.014

ASPECTS = Alberta Stroke Program Early CT Score, CI = confidence interval, DWI = diffusion-weighted image, NIHSS = National Institutes of Health Stroke Scale, OR = odds ratio

pendent predictors of clinical outcome after endovascular therapy in patients with anterior circulation tandem occlusions. These previous studies have found that age, baseline NIHSS, time from symptom onset to carotid recanalization, successful intracranial reperfusion, and baseline ASPECTS were independent predictors of clinical outcome (4, 19, 32, 33). Our study is different from previous studies in that the current study had large sample size and included not only patients with tandem occlusions but also those without intracranial arterial occlusion. In addition, all endovascular therapy was started within 6 hours of symptom onset in the present study. Of note, post-treatment parenchymal hemorrhage was identified as one of the independent predictors for functional outcome in our study. The risk of intracranial hemorrhage might be expected after emergent CAS because antiplatelet and/or anticoagulation therapies are needed for preventing acute stent thrombosis (15, 21). Additional use of intravenous r-tPA, intra-arterial urokinase, or intra-arterial glycoprotein IIb/IIIa inhibitor during procedure may further increase the risk of intracranial hemorrhage (34). In the present study, 58.1% of patients received intravenous r-tPA before endovascular procedure, 11.8% received intraarterial urokinase infusion, and 90.3% received aspirin and clopidogrel after endovascular procedure. Glycoprotein IIb/IIIa inhibitor was not administered in our patients. In the present study, the rates of parenchymal hemorrhage (8.6%) and symptomatic hemorrhage (6.5%) were comparable to those of previous reports, which range 0–18% for parenchymal hemorrhage, and 0–11% for symptomatic hemorrhage (19-27, 35).

Stent thrombosis is rare, but critical complication after elective CAS (4, 36). The risk of periprocedural or delayed stent thrombosis may be higher in the setting of emergent CAS than the elective CAS, because premedication of antiplatelet agents is not possible in the emergent setting. Several studies reported the occurrence of stent thrombosis after emergent CAS, with the incidence of 0–19.1% (4, 36-38). Pop et al. (38) observed delayed stent thrombosis within 1–5 days in a 19.1% (14/73) of patients and found that stent thrombosis was an independent predictor of unfavorable outcome in patients treated with emergent CAS for acute stroke with tandem lesions. Similarly, all patients with stent thrombosis showed unfavorable outcome (mRS 3–6) in our study. There is no consensus regarding optimal antithrombotic therapy in acute stroke patients receiving emergent CAS. Eker et al. (33) reported that stent thrombosis occurred within 7 days in 10.3% (10/98) of patients after emergent CAS. In their

study, patients received 250 mg bolus of aspirin intravenously before stenting and then 75 mg clopidogrel was administered after the procedure if there was no hemorrhage on follow-up CT scan. Pop et al. (38) reported that stent occlusion rate was significantly higher in patients received IV aspirin (250 mg) alone than those received IV aspirin and oral clopidogrel (300 mg) (28.2% vs. 8.8%, $p = 0.04$). In our study, patients received low dose oral aspirin plus clopidogrel after the procedure. Despite the nonuse of antiplatelet agents before or during the endovascular procedure, the incidence of stent thrombosis (7.8%, $n = 6/77$) was relatively low. In our study, all cases of stent thrombosis were found on day 3 CT angiography and these patients did not receive further treatment for stent thrombosis. The optimal antithrombotic regimen for patients who are undergoing emergent CAS for acute cervical ICA stenocclusive disease should be determined in further studies.

Our study showed that concomitant anterior cerebral artery occlusion was significantly associated with unfavorable outcome: 87.5% of patients (7/8) with concomitant anterior cerebral artery occlusion had unfavorable outcome. This finding is consistent with that of a recent study by Chalumeau et al. (39) They reported that procedural anterior cerebral artery embolism was significantly associated with a lower rate of favorable outcome and a higher mortality in patients with anterior circulation stroke. Concomitant anterior cerebral artery occlusion negatively impacts collateral circulation and may offset the effect of successful reperfusion after thrombectomy.

The present study had several limitations including single center-based, retrospective and non-randomized study design. All patients with tandem occlusions were treated with proximal to distal approach (CAS first then intracranial reperfusion therapy). In addition, intracranial recanalization therapy was not consistent throughout the study period. Although mechanical thrombectomy with stent retriever was the primary endovascular method, intraarterial urokinase infusion was performed in the early study period.

In conclusion, the present study suggests that emergent CAS within 6 hours after symptom onset seems effective and safe for treating acute stroke attributable to occlusion or high-grade stenosis of cervical ICA. Intracranial reperfusion status, age, initial infarction severity, and posttreatment parenchymal hemorrhage were independent predictors of favorable outcome in this patient group.

Author Contributions

Conceptualization, Y.W.; data curation, Y.W., M.G.I.; formal analysis, Y.W., M.G.I.; investigation, M.G.I., B.B.H., K.S.K., L.Y.Y., L.H.; methodology, M.G.I., B.B.H., K.S.K., L.Y.Y., L.H.; project administration, Y.W.; supervision, Y.W.; visualization, M.G.I., B.B.H., K.S.K., L.Y.Y., L.H.; writing—original draft, M.G.I.; and writing—review & editing, Y.W.

Conflicts of Interest

The authors have no potential conflicts of interest to disclose.

REFERENCES

1. Kim YS, Garami Z, Mikulik R, Molina CA, Alexandrov AV; CLOTBUST Collaborators. Early recanalization rates and clinical outcomes in patients with tandem internal carotid artery/middle cerebral artery occlusion and isolated middle cerebral artery occlusion. *Stroke* 2005;36:869-871
2. Rubiera M, Ribo M, Delgado-Mederos R, Santamarina E, Delgado P, Montaner J, et al. Tandem internal ca-

rotid artery/middle cerebral artery occlusion: an independent predictor of poor outcome after systemic thrombolysis. *Stroke* 2006;37:2301-2305

3. Heck DV, Brown MD. Carotid stenting and intracranial thrombectomy for treatment of acute stroke due to tandem occlusions with aggressive antiplatelet therapy may be associated with a high incidence of intracranial hemorrhage. *J Neurointerv Surg* 2015;7:170-175
4. Yoon W, Kim BM, Kim DJ, Kim DI, Kim SK. Outcomes and prognostic factors after emergent carotid artery stenting for hyperacute stroke within 6 hours of symptom onset. *Neurosurgery* 2015;76:321-329
5. Jovin TG, Chamorro A, Cobo E, De Miquel MA, Molina CA, Rovira A, et al. Thrombectomy within 8 hours after symptom onset in ischemic stroke. *N Engl J Med* 2015;372:2296-2306
6. Berkhemer OA, Fransen PS, Beumer D, Van den Berg LA, Lingsma HF, Yoo AJ, et al. A randomized trial of intraarterial treatment for acute ischemic stroke. *N Engl J Med* 2015;372:11-20
7. Goyal M, Demchuk AM, Menon BK, Eesa M, Rempel JL, Thornton J, et al. Randomized assessment of rapid endovascular treatment of ischemic stroke. *N Engl J Med* 2015;372:1019-1030
8. Adams HP Jr, Bendixen BH, Leira E, Chang KC, Davis PH, Woolson RF, et al. Antithrombotic treatment of ischemic stroke among patients with occlusion or severe stenosis of the internal carotid artery: a report of the trial of org 10172 in acute stroke treatment. *Neurology* 1999;53:122-125
9. Meves SH, Muhs A, Federlein J, Büttner T, Przuntek H, Postert T. Recanalization of acute symptomatic occlusions of the internal carotid artery. *J Neurol* 2002;249:188-192
10. Behme D, Molina CA, Selim MH, Ribo M. Emergent carotid stenting after thrombectomy in patients with tandem lesions. *Stroke* 2017;48:1126-1128
11. Jacquin G, Poppe AY, Labrie M, Daneault N, Deschaintre Y, Gioia LC, et al. Lack of consensus among stroke experts on the optimal management of patients with acute tandem occlusion. *Stroke* 2019;50:1254-1256
12. Linfante I, Llinas RH, Selim M, Chaves C, Kumar S, Parker RA, et al. Clinical and vascular outcome in internal carotid artery versus middle cerebral artery occlusions after intravenous tissue plasminogen activator. *Stroke* 2002;33:2066-2071
13. Rubiera M, Alvarez-Sabín J, Ribo M, Montaner J, Santamarina E, Arenillas JF, et al. Predictors of early arterial reocclusion after tissue plasminogen activator-induced recanalization in acute ischemic stroke. *Stroke* 2005;36:1452-1456
14. Bhatia R, Hill MD, Shobha N, Menon B, Bal S, Kochar P, et al. Low rates of acute recanalization with intravenous recombinant tissue plasminogen activator in ischemic stroke: real-world experience and a call for action. *Stroke* 2010;41:2254-2258
15. Molina CA, Montaner J, Arenillas JF, Ribo M, Rubiera M, Alvarez-Sabín J. Differential pattern of tissue plasminogen activator-induced proximal middle cerebral artery recanalization among stroke subtypes. *Stroke* 2004;35:486-490
16. Christou I, Felberg RA, Demchuk AM, Burgin WS, Malkoff M, Grotta JC, et al. Intravenous tissue plasminogen activator and flow improvement in acute ischemic stroke patients with internal carotid artery occlusion. *J Neuroimaging* 2002;12:119-123
17. Imai K, Mori T, Izumoto H, Watanabe M, Majima K. Emergency carotid artery stent placement in patients with acute ischemic stroke. *AJNR Am J Neuroradiol* 2005;26:1249-1258
18. Jovin TG, Gupta R, Uchino K, Jungreis CA, Wechsler LR, Hammer MD, et al. Emergent stenting of extracranial internal carotid artery occlusion in acute stroke has a high revascularization rate. *Stroke* 2005;36:2426-2430
19. Kwak HS, Hwang SB, Jin GY, Hippe DS, Chung GH. Predictors of functional outcome after emergency carotid artery stenting and intra-arterial thrombolysis for treatment of acute stroke associated with obstruction of the proximal internal carotid artery and tandem downstream occlusion. *AJNR Am J Neuroradiol* 2013;34:841-846
20. Malik AM, Vora NA, Lin R, Zaidi SF, Aleu A, Jankowitz BT, et al. Endovascular treatment of tandem extracranial/intracranial anterior circulation occlusions: preliminary single-center experience. *Stroke* 2011;42:1653-1657
21. Nedeltchev K, Brekenfeld C, Remonda L, Ozdoba C, Do DD, Arnold M, et al. Internal carotid artery stent implantation in 25 patients with acute stroke: preliminary results. *Radiology* 2005;237:1029-1037
22. Papanagiotou P, Roth C, Walter S, Behnke S, Grunwald IQ, Viera J, et al. Carotid artery stenting in acute stroke. *J Am Coll Cardiol* 2011;58:2363-2369
23. Behme D, Mpotsaris A, Zeyen P, Psychogios MN, Kowoll A, Maurer CJ, et al. Emergency stenting of the ex-

tracranial internal carotid artery in combination with anterior circulation thrombectomy in acute Ischemic stroke: a retrospective multicenter study. *AJNR Am J Neuroradiol* 2015;36:2340-2345

24. Cohen JE, Gomori JM, Rajz G, Itshayek E, Eichel R, Leker RR. Extracranial carotid artery stenting followed by intracranial stent-based thrombectomy for acute tandem occlusive disease. *J Neurointerv Surg* 2015;7:412-417
25. Puri AS, Kühn AL, Kwon HJ, Khan M, Hou SY, Lin E, et al. Endovascular treatment of tandem vascular occlusions in acute ischemic stroke. *J Neurointerv Surg* 2015;7:158-163
26. Son S, Choi DS, Oh MK, Kim SK, Kang H, Park KJ, et al. Emergency carotid artery stenting in patients with acute ischemic stroke due to occlusion or stenosis of the proximal internal carotid artery: a single-center experience. *J Neurointerv Surg* 2015;7:238-244
27. Kim B, Kim BM, Bang OY, Baek JH, Heo JH, Nam HS, et al. Carotid artery stenting and intracranial thrombectomy for tandem cervical and intracranial artery occlusions. *Neurosurgery* 2020;86:213-220
28. Ferguson GG, Eliasziw M, Barr HW, Clagett GP, Barnes RW, Wallace MC, et al. The North American Symptomatic Carotid Endarterectomy Trial : surgical results in 1415 patients. *Stroke* 1999;30:1751-1758
29. Yoon W, Jung MY, Jung SH, Park MS, Kim JT, Kang HK. Subarachnoid hemorrhage in a multimodal approach heavily weighted toward mechanical thrombectomy with solitaire stent in acute stroke. *Stroke* 2013;44:414-419
30. Zaidat OO, Yoo AJ, Khatri P, Tomsick TA, Von Kummer R, Saver JL, et al. Recommendations on angiographic revascularization grading standards for acute ischemic stroke: a consensus statement. *Stroke* 2013;44:2650-2663
31. Hacke W, Kaste M, Fieschi C, Von Kummer R, Davalos A, Meier D, et al. Randomised double-blind placebo-controlled trial of thrombolytic therapy with intravenous alteplase in acute ischaemic stroke (ECASS II). Second European-Australasian Acute Stroke Study Investigators. *Lancet* 1998;352:1245-1251
32. Grigoryan M, Haussen DC, Hassan AE, Lima A, Grossberg J, Rebello LC, et al. Endovascular treatment of acute ischemic stroke due to tandem occlusions: large multicenter series and systematic review. *Cerebrovasc Dis* 2016;41:306-312
33. Eker OF, Bühlmann M, Dargazanli C, Kaesmacher J, Mourand I, Gralla J, et al. Endovascular treatment of atherosclerotic tandem occlusions in anterior circulation stroke: technical aspects and complications compared to isolated intracranial occlusions. *Front Neurol* 2018;9:1046
34. Zhu F, Labreuche J, Haussen DC, Piotin M, Steglich-Arnholm H, Taschner C, et al. Hemorrhagic transformation after thrombectomy for tandem occlusions. *Stroke* 2019;50:516-519
35. Sivan-Hoffmann R, Gory B, Armoiry X, Goyal M, Riva R, Labeyrie PE, et al. Stent-retriever thrombectomy for acute anterior ischemic stroke with tandem occlusion: a systematic review and meta-analysis. *Eur Radiol* 2017;27:247-254
36. Xiromeritis K, Dalainas I, Stamatakos M, Katsikas V, Martinakis V, Stamatelopoulos K, et al. Acute carotid stent thrombosis after carotid artery stenting. *Eur Rev Med Pharmacol Sci* 2012;16:355-362
37. Rangel-Castilla L, Rajah GB, Shakir HJ, Shallwani H, Gandhi S, Davies JM, et al. Management of acute ischemic stroke due to tandem occlusion: should endovascular recanalization of the extracranial or intracranial occlusive lesion be done first? *Neurosurg Focus* 2017;42:E16
38. Pop R, Zinchenko I, Quenardelle V, Mihoc D, Manisor M, Richter JS, et al. Predictors and clinical impact of delayed stent thrombosis after thrombectomy for acute stroke with tandem Lesions. *AJNR Am J Neuroradiol* 2019;40:533-539
39. Chalumeau V, Blanc R, Redjem H, Ciccio G, Smajda S, Desilles JP, et al. Anterior cerebral artery embolism during thrombectomy increases disability and mortality. *J Neurointerv Surg* 2018;10:1057-1062

급성 전방순환 뇌경색 환자에서 응급 경동맥 스텐트 삽입술 후 양호한 임상 결과의 예측인자

문경일¹ · 백병현¹ · 김슬기² · 이윤영¹ · 이효재¹ · 윤 응^{1*}

목적 이 연구는 경동맥 폐쇄성 병변에 의해 발생한 급성 뇌경색 환자에서 응급 경동맥 스텐트 삽입술 후 양호한 임상 결과의 독립적인 예측인자를 알아보고자 하였다.

대상 및 방법 경동맥 폐쇄성 병변에 의한 급성 뇌경색 증상 발생 후 6시간 이내에 응급 경동맥 스텐트 삽입술을 시행 받은 93명의 환자를 대상으로 하였다. 양호한 임상 결과를 보인 군과 불량한 임상 결과를 보인 군 간의 인자들을 비교하였으며, 양호한 임상 결과(3개월째 modified Rankin Scale 2 이하)를 예측하는 독립인자를 알아보기 위하여 로지스틱 회귀 분석을 사용하였다.

결과 76명(81.7%)의 환자가 두개내 중복폐색을 동반하였으며, 이들 중 55명이 두개내 재개통 치료를 시행 받았다. 전체적인 혈관 재개통 성공률은 74.2%(69/93)였다. 3개월째 양호한 임상 결과의 비율은 51.6%(48/93)였으며 사망률은 6.5%(6/93)였다. 이분형 로지스틱 회귀분석에서 diffusion-weighted imaging-Alberta Stroke Program Early CT Score [odds ratio (이하 OR), 1.487; 95% confidence interval (이하 CI), 1.018–2.173, $p = 0.04$], 성공적인 재관류(OR, 5.199; 95% CI, 1.566–17.265, $p = 0.007$), 뇌실질 출혈(OR, 0.042; 95% CI, 0.003–0.522, $p = 0.014$) 등이 양호한 임상 결과를 예측하는 독립인자였다.

결론 초기 뇌경색 크기, 혈관 재관류, 그리고 실질성 뇌출혈 등이 급성 뇌경색 환자에서 응급 경동맥 스텐트 삽입술 후 양호한 임상 결과를 예측하는 독립인자였다.

¹전남대학교 의과대학 영상의학교실, ²화순전남대학교병원 영상의학과