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FULL PAPER

Endovascular therapy of acute ischemic stroke related to tandem occlusion: comparison of occlusion and severe stenosis of the proximal cervical internal carotid artery

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Objective: Strokes related to tandem occlusions of the internal carotid artery (ICA) and a major intracranial artery are associated with poor clinical outcome. We evaluated the clinical efficacy of endovascular approach for the management of these lesions. We also compared the clinical outcomes regarding the type of cervical ICA lesions; complete occlusion vs severe stenosis.

Methods: We retrospectively reviewed 42 patients with acute ischemic stroke who underwent endovascular treatment for tandem lesions between January 2011 and April 2017. After dividing the patients into two groups according to lesion type of the proximal cervical ICA (complete occlusion and severe stenosis), we analyzed demographic data, angiographic findings and clinical outcomes. A modified Rankin Scale score ≤ 2 was defined as a favorable clinical outcome.

Results: Of 42 patients, 27 patients (64.3%) had complete occlusion of the cervical ICA, and the remaining 15 had

high-grade stenosis. Successful stenting was performed in all patients with favorable clinical outcomes (27/42, 64.3%). Successful reperfusion score (thrombolysis in cerebral infarction $\geq 2b$) was 78.6%; occlusion group (18/27, 66.7%) vs stenosis group (15/15, 100%) of cases. Mean modified Rankin Scale score at 90 days was 2.36 ± 1.83 . The rate of favorable clinical outcome was higher in stenosis group (11/15, 73.3%) than that of occlusion group (16/27, 59.3%) with no statistically significant difference ($p = 0.506$).

Conclusion: Acute endovascular treatment of carotid artery tandem lesions is a technically feasible and clinically effective intervention regardless of the lesion type in proximal cervical ICA.

Advances in knowledge: Our study supports the results of previous studies in which endovascular therapy has a favorable clinical outcome in carotid artery tandem occlusion.

INTRODUCTION

Stroke related to tandem occlusion of the cervical internal carotid artery (ICA) with concomitant lesion of the associated intracranial artery occurs in approximately 15% of large-vessel acute ischemic strokes.¹ In clinical practice, tandem occlusion stroke is a therapeutic challenge because of its poor prognosis.² Intravenous thrombolysis (IVT) is known for ineffective clinical outcomes because of poor recanalization rates of approximately 8–9% during the first

2 h, reported in previous studies.^{3–6} Although endovascular treatment is increasingly performed in acute stroke with large-vessel occlusion, limited evidence of endovascular approach exists for tandem occlusion strokes.^{7–13}

In daily practice, there are several considerations in determining the appropriate endovascular interventions in patients with acute tandem occlusion including technical difficulty related to blind navigation of ICA unlike stenotic

ICA, relatively high risk of complications, such as embolization and dissection, and long-term prognosis of patients. Further, subintimal angioplasty or recanalization of occluded arteries is a well-known technique for treating totally occluded coronary arteries, iliac arteries, and peripheral arterial disease. This technique is rarely used in patients with sudden occlusion of the carotid artery with acute ischemic stroke because the nature of occlusion is different.

Therefore, the aim of this study was to describe the clinical experience at our institution (Gyeongsang National University Hospital) involving patients with acute ischemic stroke-related tandem occlusion of the ICA, and to investigate the clinical efficacy and outcomes of endovascular approach regardless of the lesion type.

METHODS AND MATERIALS

Patients

The Institutional Review Board approved this study; informed consent was waived because of the retrospective nature of the study. From January 2011 to April 2017 we identified 68 patients who underwent emergency carotid artery stenting (eCAS) procedure for acute ischemic stroke and documented severe stenosis or occlusion of cervical ICA in magnetic resonance (MR) angiography within 12 h of visiting the emergency department. Based on a review of charts, images and discharge reports, we retrospectively reviewed and analyzed data of 49 patients who arrived within 8 h of acute ischemic stroke symptoms or with unclear-onset stroke within 12 h from "last normal time" because of intracranial occlusion with severe stenosis or occlusion of cervical ICA and conducted eCAS with intracranial thrombectomy. Seven patients with arterial dissection ($n = 6$) or cardiogenic embolic source ($n = 1$) were excluded (Figure 1). In the presence of atherosclerotic stenosis, the brain tissue has some adaptation to ischemia, however, there is no adaptation of the brain tissue in case of the arterial dissection. Therefore, we excluded the patients with arterial dissection to maintain homogeneity by limiting the patients to atherosclerotic stenosis or occlusion. In addition, we also excluded the patient with cardiogenic embolism because there was no underlying stenosis in the proximal ICA, in this patient and a stent was deployed due to inadvertent arterial dissection during the procedure.

Finally, 42 patients (34 males and 8 females, mean age: 70.9 ± 8.8) with atherosclerotic stenosis or occlusion of cervical ICA and

additional occlusion of the middle cerebral artery (MCA, M1 or M2 segment), anterior cerebral artery (ACA), or distal ICA were included in this study.

Stroke MRI and decision-making

All patients underwent MRI under acute ischemic stroke protocol using a 3 T (Ingenia; Philips, Eindhoven, Netherlands) or 1.5 T (Avanto; Siemens, Erlangen, Germany) MR scanner. MRI protocol consisted of diffusion-weighted images (DWI) with b-values 0 and 2000, gradient echo images (GRE), fluid-attenuated inversion recovery (FLAIR) images, gadolinium-enhanced T_1 weighted images, and gadolinium-enhanced MR angiography of the major cervical and intracranial arteries, and perfusion-weighted MR images (PWI). Patients were included for endovascular treatment if they had DWI lesions covering less than one-third of the MCA territory, and/or a perfusion-weighted MR image/DWI mismatch of more than one-third on visual assessment. Patients were eligible for recanalization if they had NIHSS > 4 or a relevant functional deficit.

Interventional procedure

29 of the 42 patients (69%) received IVT using recombinant tissue plasminogen activator (rtPA, Acylase; Boehringer Ingelheim, Basel, Switzerland) prior to the endovascular procedure. Patients presenting within 4.5 h of symptom onset and without contraindications to IVT were treated immediately with rtPA (0.9 mg kg^{-1}). In the absence of immediate neurological improvement, they were transferred rapidly to the interventional room. In contrast, patients who presented after 4.5 h of symptom onset did not undergo systemic thrombolysis, but were transferred immediately to the intervention suite.

Interventional procedures in the angiography room equipped with a biplane angiography (Artis Zee Biplane; Siemens, Erlangen, Germany) entailed a transfemoral approach under local anesthesia and a femoral sheath was placed. Four-vessel angiography confirmed collateral flow from anterior and posterior communicating arteries, and the presence of concomitant intracranial artery occlusion. A 6 Fr Shuttle was placed in the ipsilateral common carotid artery, and a 0.014-inch microwire was passed through the cervical ICA stenosis or occlusion. We navigated to distal ICA using a microwire and microcatheter and performed selective angiography to confirm tandem distal occlusion. A self-expandable stent was advanced over the microwire and positioned across occluded cervical ICA after pre-dilatation using a 4- or 5-mm balloon (Aviator plus PTA balloon, Codris, Miami Lakes, FL; Ultra-soft SV balloon, Boston Scientific). The choice of self-expandable stent was determined according to the ICA course. A closed-cell stent (Carotid WallStent; Boston Scientific) was selected in a relatively straight course and an open-cell stent (RX Acculink carotid stent; Abbott Vascular) was used in curved course. If the stenosis did not fully expand despite pre-dilatation and stenting, selected patients underwent cautious post-dilatation using a 5- or 6-mm balloon.

Intracranial thrombectomy involved a microcatheter advanced through the thrombus, and the tip was located distal to the thrombus. Mechanical thrombectomy with a stent-retriever

Figure 1. Flow diagram showing screening and selection of patients.

device (Solitaire; Covidien, or Eric; MicroVention) or Penumbra system (Penumbra; Alameda, California) was performed. Thrombectomy was performed by pulling back the device and microcatheter concurrently under continuous aspiration through the intermediate catheter (6 Fr Neuron catheter; Penumbra; Alameda, California; or 5 Fr Sofia catheter; MicroVention). Thrombectomy was repeated in case of incomplete recanalization.

Clopidogrel and aspirin dosage before the endovascular procedure for eCAS differed according to the use of rtPA. If a patient received rtPA along with a loading dose of atorvastatin (80 mg day⁻¹), a maintenance dose of clopidogrel (75 mg) with aspirin (100 mg) and atorvastatin (80 mg day⁻¹) was started 24 h after rtPA infusion. However, in the absence of rtPA regimen, a loading dose of clopidogrel (300–600 mg) with aspirin (300 mg) and atorvastatin (80 mg day⁻¹) was prescribed followed by a maintenance dose of clopidogrel (75 mg) with aspirin (100 mg) and atorvastatin (80 mg day⁻¹) administered continuously the day after eCAS. The initial loading dose of clopidogrel was decided on by each clinician.

Clinicoradiological assessment and follow-up

We defined technical success of eCAS by at least recovery of ICA flow with recanalization and graded intracranial angiographic results according to thrombolysis in cerebral infarction (TICI) scores. A TICI score $\geq 2b$ suggested successful recanalization. All post-treatment CT scans were repeated immediately and 24 h after the procedure to detect intracranial hemorrhage or other complications such as encephaledema. MRI was used to check the extent of infarction within 3–5 days after the procedure. Secondary bleeding complication were reported using the European Cooperative Acute Stroke Study III classification (HI-1/HI-2/PH-1/PH-2).¹⁴ All CT, MR, and angiographic images were evaluated in consensus by two neurointerventionists.

NIHSS scores within 48 h and at discharge, as well as modified Rankin Scale (mRS) scores at 3 months were assessed by neurologists at the stroke center. NIHSS improvement of at least 4 points compared with initial NIHSS or an NIHSS of 0–2 at 7 days after recanalization suggest early neurological improvement. An mRS of 0–2 at 90 days defined favorable clinical outcome.

Patients undergoing endovascular treatment were discharged with dual antiplatelet drugs (100 mg day⁻¹ aspirin, 75 mg day⁻¹ clopidogrel) and 40–80 mg day⁻¹ atorvastatin with instructions to continue for at least 90 days after procedure. Patients underwent a neurological examination on the day of discharge and on the day of their visit to the outpatient clinic. Follow-up imaging and neurological evaluation at 6 and 12 months was recommended for all patients after procedure and annually thereafter.

Statistical analysis

The data were tested for normal distribution using a Kolmogorov–Smirnov test. Normally distributed variables, such as age at the time of diagnosis and primary tumor size, were compared using independent *t*-test, and then expressed as the mean $\pm$ standard deviation. Group comparisons of categorical variables were

Table 1. Clinicoradiological characteristics of patient population

Age, years	70.9 $\pm$ 8.8 (46–88)
Female	8/42 (19)
Initial NIHSS	13.2 $\pm$ 5.9 (4–24)
Symptom to arrival, min	188.9 $\pm$ 151.8 (30–600)
Arrival to groin puncture, min	89.1 $\pm$ 50.1 (19–320)
Cervical ICA stenosis, %	97.6 $\pm$ 5.5 (80–100)
Intracranial occlusion site	
ICA-T	7/42 (16.7)
MCA-M1	22/42 (52.4)
MCA-M2	12/42 (28.6)
ACA	1/42 (2.4)

Note—Values are shown as mean $\pm$ standard deviation (range), n/N (%); NIHSS, National Institutes of Health Stroke Scale; ICA, internal carotid artery; MCA, middle cerebral artery; ACA, anterior cerebral artery.

performed using the χ^2 test or, Fisher's exact test for small cell values. Subsequently, a multivariate logistic regression analysis was performed for variables at the $p < 0.1$ level of statistical significance. All statistical analyses were performed using the IBM SPSS Statistics 24.0.0.0 software package (SPSS, Chicago, IL).

RESULTS

Patients' characteristics and results of endovascular treatment are listed in [Tables 1 and 2](#). Representative cases of occlusion and stenosis are presented in [Figures 2 and 3](#).

Patient population and interventional results

The mean NIHSS score of the enrolled patients at the initial neurological examination was 13.2 $\pm$ 5.9 (range, 4–24), and all the patients had a NIHSS score of at least 4 on admission. Of 42 patients, 27 (64.3%) had total occlusion of proximal ICA, and 15 (35.7%) had severe stenosis (80–99%) on the initial diagnostic cerebral angiography. Concomitant occlusions of intracranial arteries were localized as follows: distal ICA (7/42, 16.7%), MCA M1 segment (22/42, 52.4%), MCA M2 segment (12/42, 28.6%), and ACA (1/42, 2.4%). The mean procedure time was 73.7 $\pm$ 25.9 min (range, 40–140). The procedural duration was shorter in the stenotic group than in the occluded group ($p = 0.051$).

Stenting of proximal ICA was successful in all 42 cases using 2 different stents: Carotid WallStent (closed cell type, 33/42 = 78.6%) and RX Acculink carotid stent (open cell type, 9/42 = 21.4%). In 36 patients (85.7%), additional intracranial mechanical thrombectomy involved 23 who received Penumbra suction thrombectomy and 13 who underwent stent-retriever thrombectomy (Solitaire: 11, Eric: 2). Distal protection device (Emboshield; Abbott Vascular, Redwood City, CA; or Spider FX; EV3, Plymouth, MN) was used in 12 of 42 patients (28.6%) with large burden of thrombus in proximal ICA. Median groin puncture to recanalization time was 72.5 min (range, 40–140 min). All patients achieved a TICI score $\geq 2a$. Successful recanalization

Table 2. Clinicoradiological outcomes after endovascular treatment according to lesion type of the cervical internal carotid artery

	Cervical occlusion (<i>n</i> = 27)	Cervical stenosis (<i>n</i> = 15)	<i>p</i> -value
TICI 2b-3 [n (%)]	18 (66.7)	15 (100)	0.016 ^a
TICI 3 [n (%)]	10 (37)	9 (60)	0.43
Procedure time (min)	79.3 ± 27.0	63.7 ± 17.5	0.051 ^a
Mean mRS at 90 days	2.44	2.2	0.69
mRS ≤2 [n (%)]	16 (59.3)	11 (73.3)	0.51
Mortality at 90 days [n (%)]	3 (11.1)	1 (6.7)	1.00
Mean NIHSS after 24–48 h	7.93 ± 7.92	5.67 ± 5.72	0.35
Early neurological improvement [n (%)]	19/27 (70.4)	11/15 (73.3)	1.00
Parenchymal hemorrhage			
PH-1 ([n (%)])	7 (25.9)	5 (33.3)	0.73
PH-2	4 (14.8)	2 (13.3)	1.00

^aNote - Values are shown as mean ± SD (range), n/N (%); TICI, Thrombolysis in Cerebral Infarction; mRS, modified Rankin Score; NIHSS, National Institutes of Health Stroke Scale, **p* < 0.1.

(TICI ≥2b) was achieved in 33 patients (78.6%) and complete recanalization (TICI 3) was achieved in 19 patients (45.2%). Successful recanalization rates (occluded group; 66.7%, stenotic group; 100%) were significantly higher in the stenotic group (*p* = 0.016). The remaining six patients (14.3%) did not undergo intracranial thrombectomy because of risk of rupture: distal M2 occlusion (1/6, 2.4%) and spontaneous intracranial recanalization (5/6, 11.9%) (Figure 2).

Procedure-related complications occurred in three patients. One patient underwent severe bradycardia, hypotension, right side weakness and dysarthria during balloon angioplasty of cervical ICA, and angioplasty was suspended and normalized without sequelae. The other underwent cervical ICA dissection during angioplasty, and was stented without residual flap. Cerebral hyperperfusion syndrome developed in one patient (2.4%), and neurological improvement was not achieved within 24 h after procedure. Therefore, a follow-up MRI was conducted. The blood pressure and intracranial pressure were monitored intensively. The patient recovered except for proximal limb weakness and was discharged 26 days after procedure.

Clinical outcomes

30 of 42 patients (71.4%) exhibited early neurological improvement (NIHSS improvement of at least 4 points compared with initial NIHSS or an NIHSS of 0–2 on Day 7 post-recanalization) following hospitalization. Symptomatic intracerebral hemorrhage (ICH) occurred in six patients (14.3%) within 24 h after treatment, three of them were prescribed rtPA. There was no significant difference in the occurrence of symptomatic ICH between the patients groups regarding to systemic thrombolysis therapy. Of the six patients with ICH, four patients (9.5%) died including one because of pneumonia and the remaining three developed acute ICH after procedure and died despite decompressive craniectomy.

38 patients survived and were monitored for more than 3 months. The mean mRS score at 90 days was 2.36 ± 1.8 (range, 0–6) and

27 patients (64.3%) showed an mRS score of 0–2, retrospectively. 26 patients (61.9%) underwent MRI at least once during the follow-up. Only one patient had moderate in-stent restenosis in 6 month follow-up imaging. No neurologic deterioration or ischemic event occurred during the follow-up in any surviving patient.

29 of the 42 patients (69%) received IVT using rtPA prior to the endovascular procedure. The other 13 patients (31%) who presented later than 4.5 h received a loading dose of clopidogrel. 9 of these 13 patients were prescribed clopidogrel at a dose of 600 mg, and 4 patients received a dose of 300 mg. Among patients who received rtPA, there were 19 patients (19/29, 65.5%) with favorable clinical outcome. There were seven patients (7/13, 53.8%) who had a favorable clinical outcome without rtPA. There was no significant difference in favorable clinical outcome between these two groups (*p* = 0.534). Results of favorable clinical outcome predictors are summarized in Table 3. TICI 3 reperfusion (odds ratios (OR) 8.77; 95% confidence interval (CI) 1.01–76.9; *p* = 0.05) and early neurological improvement (OR 11.49; 95% CI 1.85–71.4; *p* = 0.01) were the strongest predictors of favorable clinical outcome at 90 days, whereas, age, gender, or initial NIHSS did not independently affect favorable clinical outcomes.

DISCUSSION

Approximately 10–20% of patients with acute ischemic stroke manifest ipsilateral extracranial steno-occlusive carotid disease, that may causes major cerebral infarction in the presence of an additional intracranial artery occlusion of the anterior circulation.¹⁵ According to recent studies, acute cervical ICA occlusion is frequently (50–65%) detected as tandem occlusions with intracranial extensions of the clot, usually into the terminal segment of ICA or MCA branches.^{16,17} Previous studies suggest that patients with tandem occlusion have poorer outcome than those with isolated MCA occlusion.² Linfante, et al¹⁸ report that MCA occlusions have a higher proportion of recanalization (88%) within 3 days of tPA compared with tandem occlusions (31%).

Figure 2. Case example of 78-year-old male with tandem occlusion (NIHSS score 16). (a) Diagnostic angiography shows total occlusion of left proximal ICA (arrow). (b) After passing the proximal ICA occlusion using a 0.014-inch microwire, lateral projection of left internal carotid angiography shows tandem of the left distal ICA (arrow). (c) After stent placement and balloon angioplasty, lateral projection angiography shows complete restoration of left proximal ICA. (d, Post-procedural intracranial lateral projection angiography. The spontaneous recanalization of the occluded left ACA is observed. ICA, internal carotid artery; ACA, anterior cerebral artery.

Treatment of acute ischemic stroke with tandem occlusion via conventional IVT alone leads to favorable clinical outcomes in 24–30% of cases with a mortality rate of 27–55%.^{5,19} Extracranial ICA occlusions limit the exposure of distal thrombolysis to thrombolytic agents by decreasing regional perfusion pressure. Advances in endovascular treatment, confirmed the challenges associated with management of tandem occlusions. However, no consensus treatment exists for patients with acute ischemic stroke presenting with severe clinical symptoms due to tandem occlusion. A prospective survey involving a large number of tandem lesions is limited because of the rarity of the tandem occlusion.

In our study, the procedure time was significantly shorter in the stenotic group, probably because the cervical ICA stenosis

provides a distal route in the anatomy (Figure 3), but cervical ICA occlusion cannot secure a distal route. However, both groups showed high technical success regardless of cervical ICA occlusion. Previous studies reported successful navigation through an occluded vessel.²⁰ Vascular occlusion can often present a situation akin to acute coronary syndromes involving thrombus formation associated with rupture of pre-existing plaque in underlying non-critical stenosis. Thus, in acute settings, at least a few occlusive lesions of ICA origin can cause local lesions with focal unorganized thrombosis that pass relatively easily through lesions relative to peripheral arterial disease without subintimal angioplasty.

In addition, the rate of recanalization was significantly higher in the stenosis group than that of occlusion group whereas

Figure 3. Case example of 69-year-old male with acute onset of left hemispheric syndrome (NIHSS score 17). (a) Pre-procedural extracranial lateral projection angiography. Note the severe stenosis of the right proximal ICA (arrow). (b) Pre-procedural intracranial anterior to posterior projection of right internal carotid angiography. Note the tandem occlusion of the proximal portion on the right MCA M1 segment (arrow). (c) Subtracted image acquired immediately after stent deployment show recanalization of right proximal ICA (black arrow), however right MCA is still occluded (white arrow). (d) Digital subtraction angiography after deployment of the Solitaire stent shows partial restoration of vessel flow; distal stent markers (arrow) are visible. (E) After stent withdrawal, the vessel is fully recanalized to a TICI 3 state. Stenting of left proximal ICA has been performed after 2 weeks (not shown). ICA, internal carotid artery; MCA, middle cerebral artery; TICI, thrombolysis in cerebral infarction.

favorable clinical outcome, symptomatic ICH and mortality were not significantly different between the two groups in the present study. Although this study was based on fairly small sample size, we found that the rate of recanalization did not predict a favorable clinical outcome as shown in the previous studies.^{21,22} The favorable clinical outcome of the present study demonstrated better in comparison with the recent prospective study regarding to the outcome of neurothrombectomy for acute ischemic stroke.²³ However, larger number of patients for tandem lesions may

affected to reduce the favorable clinical outcome or successful recanalization rate in the previous study.²³ Therefore, there is a limitation to be a direct comparison with previous studies, but we suggest that endovascular therapy of tandem lesions can be an effective treatment option regardless of the type of cervical ICA. We reviewed 15 published studies revealing 640 cases of endovascular procedure targeting tandem lesions.^{21,22,24-36} Favorable clinical outcomes resulted in 41.2% of these patients. Recanalization in these series was successful in 77.2%, and symptomatic ICH and mortality rates were 9.2 and 19.1%, retrospectively. Several factors suggest why the favorable clinical outcome in our study is better than in previous studies. First, it may seem better merely because of our relatively small sample size. Second, the severity of patients was low, because the mean initial NIHSS was 13.2 compared to the STRATIS registry (initial NIHSS; 17.3) and the reviewed 640 cases (initial NIHSS; 15.8). Third, the results of endovascular therapy may differ depending on the experience and skill of the operator. Finally, it is possible that the mixed results of patients with different cervical ICA stenosis may have affected the overall outcome. Most studies did not disclose the ratio of the cervical ICA occluded group to the stenotic group,

Table 3. Multivariate predictors of favorable clinical outcome

Variable	OR (95% CI)	p-value
Age	0.95 (0.81–1.12)	NS
Gender, male	1.08 (0.16–7.25)	NS
Initial NIHSS	0.89 (0.73–1.29)	NS
TICI 3 [n (%)]	8.77 (1.01–76.9)	0.05
Early neurological improvement	11.49 (1.85–71.4)	0.01

NS, Not significant; TICI, thrombolysis in cerebral infarction.

making objective comparison difficult. Also, the definition of tandem occlusion in the studies was not exactly the same. Many studies have included “tandem occlusion” with severe stenosis of cervical ICA, and occasionally have combined occlusion and stenosis with “tandem lesion”. Therefore, it is necessary to clarify the definition of tandem occlusion in any future large-scale systematic review or prospective study.

In addition, the previous study have reported that stent-retriever devices showed a higher recanalization rates than Penumbra devices.³² However, similar to the data of Son et al,¹⁷ we found no statistically significant differences in recanalization rates, procedural time and complication rates between these two devices.

Most studies reported stenting of proximal ICA prior to recanalization of intracranial occlusion.^{21,22,24–35} The main advantage of the antegrade technique (proximal ICA stenting followed by intracranial thrombectomy) related to the increased likelihood of successful distal recanalization following enhanced proximal flow due to increase in distal perfusion via collaterals. Another advantage is the lower risk of vessel dissection or perforation because of non-blind navigation of ICA with the microwire and microcatheter in the group with cervical ICA occlusion. Another advantage of the antegrade technique is the improved accessibility of intracranial lesions for effective treatment with mechanical devices. The disadvantages of the antegrade technique include risk of distal embolization, which is a major safety issue. However, in our case series, the rate of distal embolization was as low as 2.4% (1/42), probably because of the use of distal protection devices in patients with large thrombotic burden in proximal ICA. Therefore, we suggest the use of distal protective devices in tandem occlusion if large burden of thrombus in proximal ICA coexists. It can reduce the clot burden and facilitate thrombectomy to distal occlusion.

Spontaneous intracranial recanalization occurs in patients with tandem occlusions after proximal revascularization.^{17,20} In our series, five patients (11.9%) showed spontaneous reperfusion of the intracranial vessel occlusion (one MCA proximal M1, and four proximal M2) immediately after pre-dilatation to proximal ICA occlusion, obviating the need for further intracranial thrombectomy (Figure 2).

Dual antiplatelet agents are recommended before and after the procedure to prevent acute or chronic in-stent thrombosis.²⁸ However, a standard medical regimen in endovascular treatment of tandem lesions has not been established. In our study, patients treated with rtPA prior to endovascular treatment were not prescribed antiplatelet agents. Patients who did not receive rtPA were administered a loading dose of antiplatelet agents, including clopidogrel (300–600 mg) and aspirin (300 mg). There were no significant differences in the clinical outcomes between rtPA-treated and untreated groups, probably because the sample was small and heterogeneous tendencies are mixed in the group. Therefore, a large sample study seems to be needed for establishing the efficacy of intravenous rtPA in endovascular treatment for tandem lesion.

There are several limitations of this study. First, there was an unavoidable selection bias because of the study’s retrospective nature. Second, it was relatively small sample size to compare statistically between the two groups. Third, the modalities of endovascular therapy differ with the passage of time in each patients, therefore, there is limitation in standardizing the treatment methods used in the present study. Lastly, the preferred regimen for each participating clinicians was different regarding to antiplatelet drug. It may have influenced the clinical outcome including rate of symptomatic ICH.

In conclusion, the endovascular multimodality approach for acute stroke because of tandem occlusion revealed reasonable efficacy, safety, technical feasibility and high rate of favorable clinical outcomes (27/42, 64.3%) regardless of the lesion type of proximal cervical ICA; occlusion group (16/27, 59.3%) vs stenosis group (11/15, 73.3%). Especially, the cervical ICA stenotic group had a short procedure time and high recanalization rate. Further prospective, randomized double-blind studies in multicenter settings should validate our findings.

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