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Mechanical thrombectomy with solitaire stent for acute internal carotid artery occlusion without atherosclerotic stenosis: dissection or cardiogenic thromboembolism

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Abstract. – BACKGROUND: In acute ischemic stroke patients, internal carotid artery occlusion with middle cerebral artery (ICA/MCA) occlusion in succession predicts a poor outcome after systemic thrombolysis. It is not known whether this occlusion subtype of the anterior circulation is due to dissections or cardiogenic thromboembolism. We aimed to find useful evidence to judge the condition with accuracy and establish reasonable treatment protocols.

PATIENTS AND METHODS: This retrospective study included 7 consecutive patients with acute ICA/MCA occlusion in succession who had undergone mechanical thrombectomy with a Solitaire stent retrieval between January 2012 and June 2013. Then we also reviewed the current literature.

RESULTS: The patients had a mean age of 56 years and a mean baseline National Institutes of Health Stroke Scale (NIHSS) score of 20. The procedure resulted in thrombolysis in cerebral ischemia (TICI) scores of 2a or better in all patients, but complete recanalization of the ICA occlusion segment was achieved in only 2 patients. Stenting was not performed in all patients. At 90 days, 1 patient was dead and 4 of the 7 patients had favorable functional outcomes (modified Rankin score (mRS) ≥ 2). We identified 9 studies with 85 patients with nonatherosclerotic acute ICA occlusion who underwent mechanical thrombectomy with Solitaire stent. The mean age was 65 years with a mean baseline National Institute Health Stroke Scale (NIHSS) score of 16 and mean time to treatment of 242 minutes. The mean time of the procedures ranged from 40-160 minutes in 9 studies. Successful recanalization was achieved in 69.4% of the patients and mortality was 16.5%. Favorable outcome (mRS ≤ 2) occurred in 42.4% of patients. Few studies stated whether complete recanalization was achieved in patients with ICA occlusion.

CONCLUSIONS: Our results and the literature review suggest that mechanical thrombectomy in acute stroke due to ICA/MCA occlusion is feasible and safe, with high rates of recanalization and favorable functional outcomes. More patients with ICA/MCA occlusion in succession could obtain favorable functional outcomes with accurate judgment of the lesion location and appropriate treatment protocols. However, there is no consensus on how to judge the correct location of the ICA dissected portion and whether stenting is appropriate.

Key Words:
Acute ischemic stroke, Internal carotid artery, Middle cerebral artery, Occlusion, Dissection, Cardiogenic thromboembolism, Solitaire stent.

Introduction

Acute ischemic stroke (AIS) is a complex disease incorporating several subtypes with different underlying pathologies that have many corresponding treatment options. These options should be individually tailored to the patient. The efficacy of mechanical thrombectomy with Solitaire stent has been proven in several clinical trials[1-9]. However, few articles have discussed the pathologies of internal carotid artery/middle cerebral artery (ICA/MCA) occlusion in succession. Therefore, we retrospectively analyzed the clinical data of patients treated with mechanical thrombectomy for acute stroke due to ICAT/MCA occlusion in succession and performed a systematic literature review. We hoped to attract valuable comments and open the subject for discussion.

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Patients and Methods

The institutional Review Board granted general permission to collect routine anonymous data on all stroke patients. A retrospective analysis was performed for 7 patients who presented to our hospital with acute symptomatic carotid occlusions in the setting of AIS between January 2012 and June 2013. Inclusion criteria: (1) age 18-80 years; (2) National Institutes of Health Stroke Scale (NIHSS) score ≥ 6; (3) time from symptom onset to puncture ≤ 6 h; (4) absence of cerebral hemorrhage; and (5) no acute infarction in one-third of the affected vascular territory on native cranial computed tomography (CT) scan. Patients with ICA occlusions due to atherosclerotic stenosis of the carotid were excluded.

All patients (Table I) were transferred to the angiography room after cranial CT scan. The diagnosis of ICA occlusion in all cases was confirmed by digital subtraction and all procedures were performed under general anesthesia. Details of the recanalization procedure and the definitions of the rate of vascular recanalization, device-related complications, symptomatic intracranial hemorrhage (sICH), and favorable functional outcomes, have been previously reported[4,7]. An 8-Fr balloon guiding catheter was not used in all patients and the procedure was repeated until a final thrombolysis in cerebral ischemia (TICI) score of 2b or 3 was reached with no more than 5 passages.

The database includes the following prospectively collected informations: patient demographics, stroke severity (as determined by the NIHSS Score), location of the arterial occlusion, procedure performed, complications, and 90 day functional outcomes. We then reviewed each patient's clinical data retrospectively to identify the stroke etiology.

Using the PubMed database and the following search terms: "internal carotid artery," "occlusion," "acute," and "thrombectomy", we identified studies published since 2005. We included only those studies of ICA occlusion which included the patient demographics, NIHSS Score, procedure performed, complications, mortality, and 90 day functional outcomes. Patients with ICA occlusions due to atherosclerotic stenosis of the carotid artery were excluded.

Results

The baseline characteristics and procedural techniques are shown in Table I. The median age was 56 years (range, 31-79) and the mean baseline NIHSS score was 20 (range, 14-24). The mean time from stroke onset to arterial access was 186 min (range, 130-285 min). Intravenous, intra-arterial, or combined thrombolytic therapy (tissue plasminogen activator or urokinase) was used in 4 patients. TICI 2a or better flow was seen in all patients, but complete recanalization of the ICA occlusion segment was achieved in only 2 of the patients. Stenting was not performed in all patients. One patient (case 7) died on the third day after the procedure. At 90 days, 4 out of 7 patients had favorable functional outcomes (modified Rankin score (mRS) ≥ 2). Information on the procedural complications was not available in all patients, but there were no complications, including sICH or stroke, in a previously unaffected territory.

The stroke etiology of the patients was confirmed by the treating interventionalist. In cases 2, 3, 4, and 6, acute ICA occlusion was due to carotid dissection, but complete recanalization of the ICA occlusion segment was not achieved in these patients. In cases 1, 5, and 7, the acute ICA occlusion was due to cardiogenic thromboembolism, and complete recanalization of the ICA occlusion segment was achieved in cases 5 and 7. Cases 2, 3, and 6 presented with classic cervical ICA dissection resulting in a flame-shaped occlusion, and ipsilateral MCA without cross-filling of contrast. Cases 1, 4, 5, and 7 presented with occlusion extending from the terminus of the ICA to the initial part of the MCA.

We identified 9 studies comprising a total of 85 patients with AIS due to ICA occlusion that met our inclusion criteria in the literature review. Demographics, procedural characteristics, and clinical results are shown in Table II.

The mean age of all patients in the 9 studies was 65 years (range, 60-74 years). Of the 85 patients, 42 were female and the mean initial NIHSS ranged from 13-24. CT and/or MRI were used to evaluate the salvaging brain tissues and the presence of hemorrhage and the mean time from stroke symptom onset to puncture was 242 minutes (range, 60-385 minutes (data available for 8 studies). The mean time of the procedures was 78 minutes (range, 40-160 minutes) in 8 studies[1-4,6-9]. Balloon-mounted guiding catheters were used in 1 of the 9 studies[4] and concurrent performance of IV thrombolysis was recorded in 7 of the 9 studies[1-5,8,9]. Concurrent endovascular interventions included IA thrombolysis and suction thrombectomy with Penumbra. Balloon angioplasty and stenting were excluded. Five stud-

Table I. Patients' demographic, clinical, and technical data.

Pt	Age	sex	Baseline NIHSS	Location of lesions		Onset to IV tPA	Procedure puncture length	Number of passes	IA lytic	TICI Post	CR	NIHSS discharge	90d mRS	etiology
1	63	F	20	R-ICA	Y	145	80	3	n	3	N	4	1	C
2	31	F	23	L-ICA	Y	130	60	3	N	3	N	2	0	D
3	44	M	24	L-ICA	N	260	120	4	y	3	N	9	3	D
4	50	M	20	R-ICA	N	200	110	3	y	3	N	2	1	D
5	73	F	18	L-ICA	N	130	80	2	N	2b	Y	11	3	C
6	51	M	20	L-ICA	Y	150	150	3	N	3	N	5	1	D
7	79	M	14	R-ICA	N	285	90	2	N	2b	Y	Dead	6	C
Mean			20			185.7	98.6	2.9		7/7		1/7	4/7	
Or %	57									(100%)		(14%)	(57%)	

NIHSS: National Institutes of Health Stroke Scale; IV tPA: Intravenous tissue plasminogen activator prior to intra-arterial intervention; IA lytic: intra-arterial thrombolytic administered during intervention; sICH: symptomatic intracranial hemorrhage; TICI post: thrombolysis in cerebral ischemia score post-intervention; 90d mRS: 90 day modified Rankin score; CR: complete recanalization of the ICA occlusion segment; NA: not available; D: dissection; C: cardiogenic thromboembolism

Table II. Demographics, procedural characteristics, and clinical results from the systematic review.

First author, reference	Sample	Mean Age	Sex M:F	Mean Baseline NIHSS	sICH	Mean time from Onset to puncture (min)	Mean Procedure length(min)	Mean Number of passes N	TICI Post 2b,3 N	90d mortality	90d mRS≤2 n
Hyun Park[1]	1	74	1:0	19	NA	60	40	3	1	0	0
A. Mpotsaris[2]	24	64									
	14:10	15	NA	182	92	NA	11	5	8		
LuisHenrique[3]	6	61	4:2	21	1	385	109	4.5	5	0	3
Carlos astano[4]	8	64	4:4	17	NA	350	85	NA	7	2	3
Kossivi Apetse[5]	6	64	2:4	19	1	NA	NA	NA	3	1	3
Yeon Hong Yoon[6]	26	69	12:14	13	0	238	44	NA	20	2	10
José E. Cohen[7]	4	61	3:1	24	1	322	59	1.75	3	1	3
Ji Eun Kim[8]	5	73	1:4	19	1	189	78	1.4	4	1	3
Tae Kwon Kim[9]	5	60	2:3	15	NA	226	160	2	5	2	3
Total	85		43:42		4				59	14	36
(Mean) or (%)		65		16	8.5%	242	78		69.4%	16.5%	42.4%

M: male; F: female; min: minutes; TICI post: thrombolysis in cerebral ischemia score post intervention; 90d mRS: 90 day modified Rankin score; NA: not available; sICH: symptomatic intracranial hemorrhage ies[1,3,7-9] included the passing time of the Solitaire stent, which varied from 1-8, with a mean passage rate range of 1.4-4.5. Successful recanalization was achieved in 59 cases (69.4%), and symptomatic hemorrhagic complications developed in 4 out of 47 cases (8.5%) in 5 studies[3,5-8]. The overall mortality rate was 16.5% (14/85). In all studies but one, which achieved mRS at 1 month[7], mRS was assessed at 3 months after the procedure. The overall rate of a favorable mRS outcome was 42.4% (36/85). Procedure-related complications included 1 subarachnoid hemorrhage in 1 study[3].

Discussion

Efficacy and Safety of Solitaire Thrombectomy

Strokes due to acute ICA occlusion are associated with an extremely poor prognosis and carry a high risk of disability or death. Although IV tissue plasminogen activator is the primary mode of therapy for strokes presenting in the first 4.5 hours, recanalization rates are especially low after IV thrombolysis in the setting of acute occlusion of the ICA[10,11], especially with ICA/MCA occlusion in succession.

Among several mechanical thrombectomy techniques and devices, the Solitaire stent has several benefits: it is self-expandable, can be used repeatedly, is easily navigated even in a tortuous carotid artery, provides immediate reperfusion in most patients after stent deployment, and requires a short procedure time. Blood flow is temporarily bypassed through an acutely occluded artery by deploying the stent[4]. A shorter time to intracranial recanalization is associated with favorable outcomes[12]. In a recent study with the Penumbra device, the mean time to recanalization was 97 ± 37 min[13]. Brekenfeld et al[14] showed that this time could be shortened to approximately 52.5 min (median time) with retrievable stent devices. The mean time of the procedures in our study and our systematic review were 99 min and 78 min, respectively, possibly because therapy is more complicated in patients with ICA occlusion than with MCA or vertebrobasilar artery occlusion.

A positive correlation exists between recanalization rates and improved functional outcomes[15]. The success of recanalization in our study and systematic review were 100% and 69.4%, respectively. A previous systematic review[16] demonstrated that the rates of favorable outcomes (36%) were significantly higher in the endovascular group than the IV thrombolysis-only group (24.9%), and a higher rate of sICH (11.1% in the endovascular treatment group vs. 4.9% the IV thrombolysis-only group) did not result in increased overall mortality rates (32.0% vs. 27.3%). However, there has been little discussion of mechanical thrombectomy devices in the literature. In our systematic review, the rate of a favorable mRS and mortality were 42.4% and 16.5%, respectively. It is possible that the outcomes in patients who received mechanical thrombectomy with the Solitaire stent for acute ICA occlusion is superior to other devices.

Our study and systematic review showed the feasibility and safety of the Solitaire stent for the treatment of acute ICA occlusion.

Acute ICA Occlusion Due to Dissection

Cerebrovascular dissections are a significant cause of stroke, accounting for 14-20% of ischemic strokes in patients younger than 50 years of age[17] and is the second most common source of large artery cerebrovascular disease after atherosclerosis[18]. The annual incidence of spontaneous carotid artery dissection is 2.5-3 per 100 000, and approximately 20% of patients have an ischemic stroke without any preceding warning signs[19]. Arterial dissection can cause ischemic stroke either by thromboemboli forming at the site of injury or as a result of hemodynamic insufficiency due to severe stenosis or occlusion (Figure 1). Available evidence strongly favors embolism as the most common cause[20, 21]. Compared with other etiologies of ischemic stroke, occlusive internal carotid artery dissection responds poorly to intravenous thrombolysis[22].

In our retrospective study, we believe that cases 2, 3, 4, and 6 presented with acute ICA occlusion due to carotid dissection, without diabetes mellitus, hypertension, atrial fibrillation, or coronary artery disease. Cases 2, 3, and 6 presented with classic cervical ICA dissection resulting in a flame-shaped occlusion, and ipsilateral MCA without cross-filling of contrast, but case 4 presented with occlusion extending from the terminus of the ICA to the initial part of the MCA (Figure 2). During the procedures for cases 2, 3, and 6, after microcatheter injections within the arterial segment with the flame-shaped occlusion, we found that the crevasse of the ICA dissection was located in the petro-cavernous or terminus segment, and was not of ICA origin. During the procedure for case 4, we captured a small thrombus with the stent on the first passage (Figure 2h), but

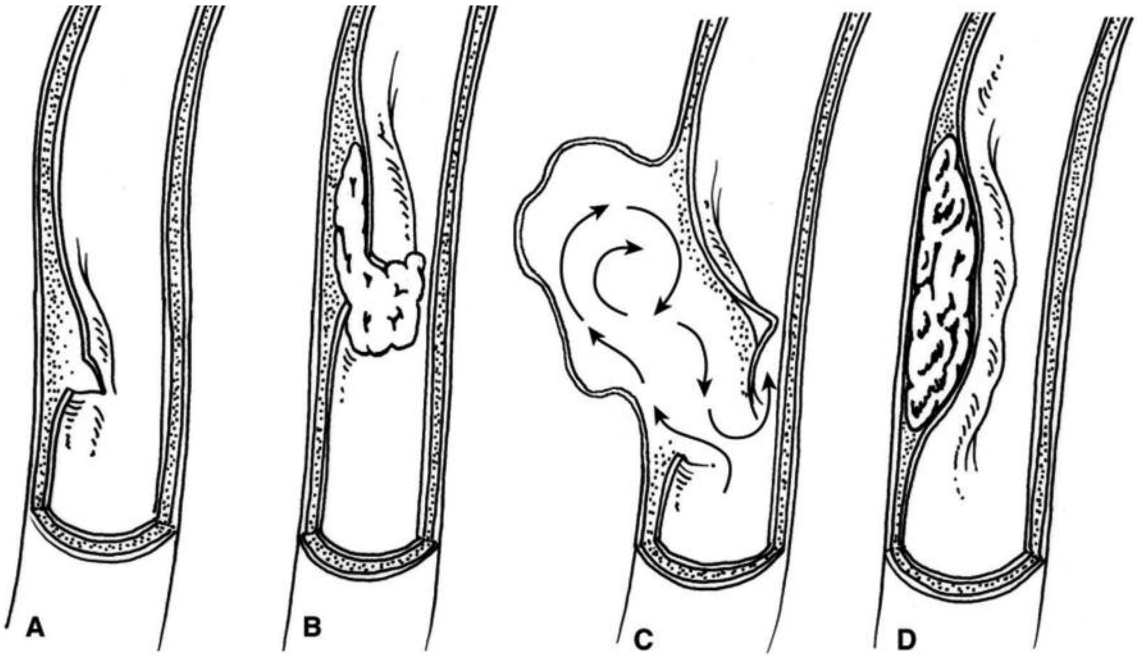

Figure 1. Arterial dissection anatomy. Schematic views of common patterns of injury. ***A,*** Intimal flap. Small disruption in the intima without an associated thrombus. Minor intimal injuries such as this may manifest only as neck pain. ***B,*** Intimal flap with subintimal and intraluminal thrombus. A larger defect than in A leads to activation of circulating platelets by contact with subendothelial tissue. The thrombus forms under the intimal flap and extends into the vessel lumen. This pattern is seen most commonly in patients with thromboembolic ischemic injury caused by the dissection. ***C,*** Dissecting aneurysm. Extension of the arterial wall defect into the subadventitial space leads to weakening and aneurysmal dilation of the adventitia. Arrows indicate turbulent flow of blood within the aneurysm. Note that adventitial tissue is present and forms the wall of the dissecting aneurysm. ***D,*** Intramural hematoma. Hemorrhage within the media with associated reduction in the vessel lumen. (Source: Matthew and Fusco[32]).

not on the second and third passes. When we slowly retrieved the deployed stent from the MCA on the fourth passage, we encountered immediate cross-filling of the right anterior circulation when the Solitaire stent was located in the supraclinoid segment. After withdrawal of the stent, repeat injection of the right ICA demonstrated persistent occlusion. We believe that case 4 was a dissection subtype: intimal flap with subintimal and intraluminal thrombus (Figure 1b). After the thrombus in the distal dissection was removed, the floating intimal flap remained and resulted in repeat occlusion of the artery, or formed a secondary thrombus. The Solitaire stent has obvious advantages over other devices, and it helps to judge the correct location of the ICA dissected portion by retrieving the deployed stent from the MCA slowly, after successful mechanical thrombectomy.

Fields et al[23], identified 980 stroke patients in the Merci registry, and dissection was designated as the probable etiology in 10 patients (1.0%). The median age was 48 years (range, 18-57), and dissected arteries included the ICA in 8 out of 10 (80%). Intracranial arterial occlusions were located in the MCA in 7 of 8 patients. The demographic characteristics and data of the patients in the study by Fields et al[23] were similar to those in our retrospective study.

In the papers by Scheperjans et al[24] and Richard et al,[25] in 5 patients younger than 59 years with MCA occlusion caused by occlusive ICA, the extracranial ICA was recanalized using two or more partially overlapping self-expanding stents. In some of these patients, angiography after stenting showed that distal ICA and MCA occlusion remained. One possible explanation for this pattern is that the ICA dissection lesions were located in the intracranial segment, not in the extracranial ICA.

In the patients younger than 50 years with acute ICA occlusion, without evidence of atherosclerotic lesion, risk factors, atrial fibrillation, or other cardiac disorders, the occlusion was probably due to dissection. It is important to judge the correct location of an ICA dissection's crevasse. Previous studies[2,24,25] have shown that stenting of the ICA dissected portion with the Solitaire stent may not result in increased risk of ICH after successful mechanical thrombectomy. An optimal treatment

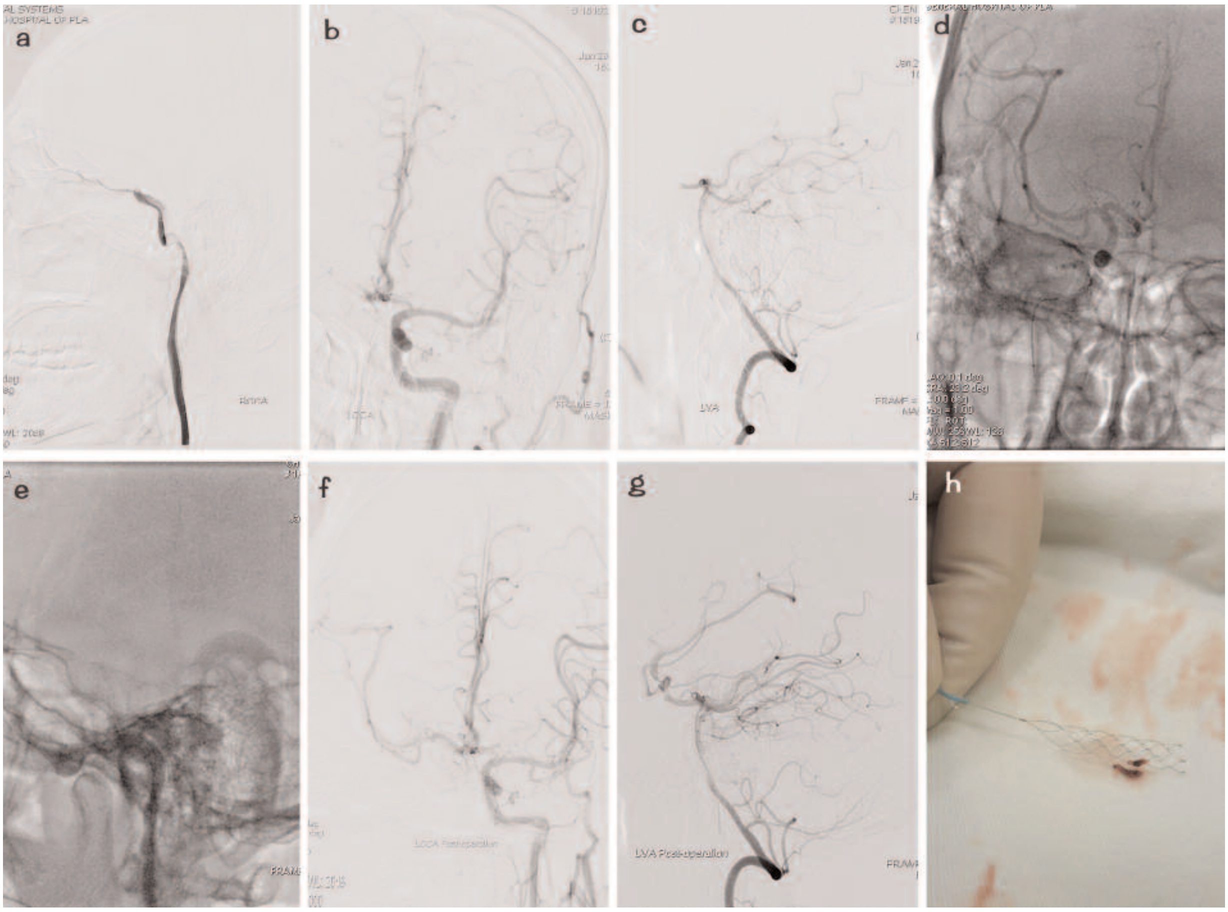

Figure 2. Case 4. A 50-year-old man with spontaneous dissection of the right ICA showing right ICA and MCA occlusion. ***A,*** Right common carotid injection demonstrating occlusion of the right ICA supraclinoid segment in the lateral view. ***B,*** Left common carotid injection showing no cross-filling of the right anterior circulation with a cutoff of the right A1 anterior cerebral artery in the anterior–posterior view. ***C,*** Left vertebral artery injection showing occlusion of the right posterior communicating artery in the lateral view. ***D,*** Immediate cross-filling of the right anterior circulation occurred when the deployed Solitaire stent was located in the supraclinoid segment in the anterior–posterior view. ***E,*** After withdrawal of the stent, repeat injection of the right ICA revealed persistent occlusion of the ICA in the lateral view. ***F,*** Repeat angiography of the left common carotid showing cross-filling across the anterior communicating artery to supply the right anterior circulation in the anterior–posterior view. ***G,*** Repeat angiography of the left vertebral artery demonstrating cross-filling across the right posterior communicating artery to supply the right MCA in the lateral view. ***H,*** Solitaire stent with retrieved small clot.

strategy should minimize the time to recanalization and repair the dissected artery to prevent hemodynamic insufficiency and intracranial reocclusion.

Acute ICA Occlusion Due to Cardiogenic Thromboembolism

Cardiogenic cerebral embolism resulting from a diversity of cardiac disorders is responsible for 20% of ischemic strokes[26]. In our retrospective study, cases 1, 5, and 7 with acute ICA occlusion may have been due to cardiogenic thromboembolism because they presented with occlusion extending from the terminus of the ICA to the initial part of the MCA. Complete recanalization of the ICA occlusion segment was achieved in cases 5 and 7.

Case 7 was a 79-year-old man with a history of hypertension and a cardiac pacemaker (Figure 3). We captured more thrombi with the stent in case 7 than in case 4, and complete recanalization of the ICA occlusion segment was achieved after two passes. Regrettably, this patient died on the third day after the procedure with death attributed to aggravation of diffuse brain swelling without intraparenchymal hemorrhage and whose relatives had refused decompressive craniectomy.

Bae et al[27] reported that 2 (5%) patients who died after aggravation of brain swelling had refused to undergo decompressive craniectomy, but did not included details of the patients' age, lesion location, or procedure length.

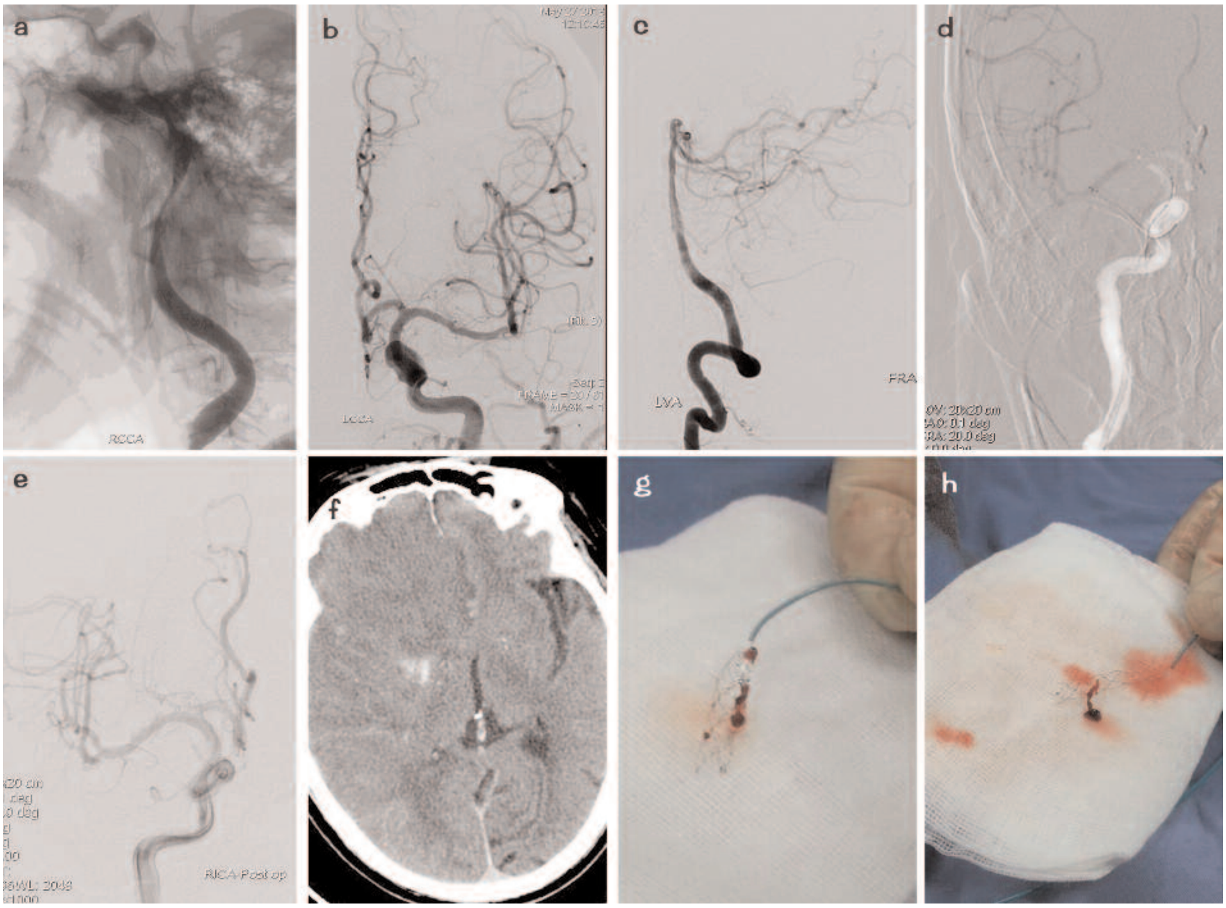

Figure 3. Case 7. A 79-year-old man with right ICA terminus occlusion and a history of hypertension and cardiac pacemaker. ***A,*** Right common carotid injection showing right ICA terminus occlusion in the lateral view. ***B,*** Left common carotid injection showing no cross-filling of the right anterior circulation in the anterior–posterior view. ***C,*** Left vertebral artery injection showing no cross-filling of the right posterior communicating artery in the lateral view. ***D,*** Right ICA angiogram showing partial arterial recanalization after stent deployment in the right MCA and ICA terminus in the anterior–posterior view (transient endovascular bypass). ***E,*** Final angiogram showing complete revascularization of the right ICA and all of its branches in the anterior–posterior view. ***F,*** and ***G,*** Solitaire stent with retrieved clot from the first and second passes, respectively. ***H,*** CT scan showing diffuse brain swelling without obvious intraparenchymal hematoma.

Hwang et al[28] reported that logistic regression analysis showed that younger age was an independent predictor of a favorable functional outcome. In our systematic review, we found that the 14 patients who died had a mean age of 77 years, greater than the mean age of 65 years of all 85 patients. The outcome of AIS is affected by time-associated complex interactions between the site of the arterial occlusion, recanalization, extent of the infarct core and ischemic penumbra, and the integrity of the blood-brain barrier[29]. The blood-brain barrier of older patients is vulnerable to AIS, which may explain aggravation of brain swelling after the procedure in some patients.

As the Solitaire stent containing the thrombus was pulled back along a curved course, some emboli detached from the catheter or stent. A balloon-guiding catheter and vigorous aspiration of blood after embolus removal in the guiding catheter can solve this problem[30,31].

In patients older than 65 years with acute ICA occlusion, with risk factors, atrial fibrillation and other cardiac disorders, without evidence of atherosclerotic lesions, the occlusion is likely due to cardiogenic thromboembolism. The use of a balloon-guiding catheter and postoperative control of blood pressure is necessary in these patients and mechanical thrombectomy for older patients with acute ICA occlusion should be administered as early as possible.

Conclusions

One of the most important prognostic factors in patients with AIS with artery occlusion is the time to recanalization and the choice of therapeutic strategy is critical for successful treatment of stroke. Our study confirms that stent retrieval with the Solitaire is safe and technically feasible for recanalization of acute ICA occlusion, and its use might lead to improved functional outcomes, whether the occlusion is due to dissection or cardiogenic thromboembolism.

Conflict of Interest

The Authors declare that they have no conflict of interests.

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