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ORIGINAL RESEARCH

Clot Removal Therapy by Aspiration and Extraction for Acute Embolic Carotid Occlusion

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BACKGROUND AND PURPOSE: The purpose of our retrospective study was to investigate the feasibility, safety, and efficacy of clot removal therapy by aspiration and extraction for patients with acute stroke with embolic internal carotid artery (ICA) occlusion.

METHODS: Of 814 consecutive patients with acute ischemic stroke admitted to our institution from March 2003 to April 2005, clot removal therapy was performed for 14. Inclusion criteria were patients (1) presenting within 6 hours of onset of cardioembolic stroke, (2) with serious neurologic symptoms defined by a National Institutes of Health Stroke Scale (NIHSS) score of at least 11, (3) without extensive high signal intensity on diffusion-weighted MR images but with decreased ipsilateral hemispheric cerebral blood flow on perfusion-weighted images (perfusion/diffusion mismatch), and (4) with total ICA occlusion on angiograms. We removed clots by aspiration and extraction with a microsnare through either a guiding or balloon guide catheter. Radiographic results, 7-day NIHSS, 3-month modified Rankin Scale, and procedure-related complications were evaluated.

RESULTS: Of 10 patients treated with the balloon guide catheter to temporarily interrupt proximal flow, 7 obtained complete or partial recanalization. The 4 patients treated with the guiding catheter had no recanalization. Of the 7 patients with recanalization, 6 had favorable 7-day neurologic and 3-month functional outcome; all showed anatomic crossflow via the anterior communicating artery. A procedure-related complication, distal embolization into the ipsilateral anterior cerebral artery, occurred in 1 patient.

CONCLUSION: Balloon guide catheter-assisted clot removal therapy for embolic ICA occlusion may provide a high recanalization rate and good clinical outcome in patients with anatomic crossflow.

Acute embolic occlusion of the internal carotid artery (ICA) results in poor outcome in many patients. At this site, it is technically difficult to achieve complete recanalization with intravenous thrombolytic therapy or localized intra-arterial fibrinolysis.[1-5] A previous study reported that additional mechanical clot disruption by percutaneous transluminal cerebral balloon angioplasty (PTCBA) following failed thrombolysis could achieve partial recanalization of embolic occlusion of the terminal ICA, but only limited clinical improvement resulted.[6,7] Recanalization of the ICA or the middle cerebral artery (MCA) is beneficial in patients with acute ischemic stroke with perfusion/diffusion mismatch demonstrated by MR images.[8] Successful recanalization by pharmacologic thrombolysis or PTCBA depends on the volume and composition of clots.[9]

Previous studies have described endovascular techniques such as mechanical clot disruption or endovascular thrombectomy for the treatment of acute ischemic stroke.[10-23] However, few reports have examined endovascular clot removal or emergency carotid endarterectomy[24] in acute embolic stroke involving the ICA. In such cases, we have attempted clot removal therapy by aspiration and extraction by using a microsnare (Soutenir, Solution, Kanagawa, Japan; or In-Time, Boston Scientific, Natick, Mass) at our institution beginning in March 2003. Since March 2004 a balloon guide catheter (Patlive; Clinical Supply, Gifu, Japan) has been substituted for the guiding catheter, aiming to temporarily interrupt proximal flow during clot removal therapy.

In a retrospective study of these patients, we investigated the feasibility, safety, and efficacy of clot removal therapy for treating embolic ICA occlusion.

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Methods

Patient Population

Of 814 consecutive patients with acute ischemic stroke admitted to our institution within 48 hours of onset from March 2003 to April 2005, 14 patients (1.7%) who fulfilled our inclusion criteria underwent clot removal therapy. A retrospective review of these patients was conducted.

Inclusion Criteria for Clot Removal Therapy

Our criteria for clot removal therapy included patients within 6 hours of onset of cardioembolic stroke defined according to the TOAST criteria,[25] having a National Institutes of Health Stroke Scale (NIHSS) score of at least 11, with neither cerebral hemorrhage nor early ischemic signs on cranial CT, and with embolic occlusion of the ICA diagnosed by emergency angiography. Additional radiologic inclusion criteria based on MR imaging (Signa EchoSpeed 1.5T, GE Yokogawa Medical System, Tokyo, Japan) were an absent or minimal area showing high signal intensity in diffusion-weighted MR images (DWI) but decreased cerebral blood flow on the ipsilateral hemisphere demonstrated by perfusion-weighted MR images (PWI)—findings that represent perfusion/diffusion mismatch. In PWI studies, relative mean transit time (rMTT) maps, relative cerebral blood volume (rCBV) maps, and rCBV divided by rMTT, calculated as relative cerebral blood flow (rCBF) maps, were created with FuncTool (Signa EchoSpeed 1.5T), when time to peak was not available for calculation of rCBF. Then, rMTT, rCBV, and rCBF were measured in

regions of interest positioned bilaterally in MCA territory. In every patient, total occlusion of the ICA was demonstrated by 3D time-of-flight MR angiography (TR/TE/flip angle, 28/6.9/20°).

Patients were excluded if they had no cardioembolic risk, had a medical contraindication for angiography, had a probable chronic or atherothrombotic ICA occlusion according to angiograms, or did not provide their own or family members' informed consent for diagnostic angiography or endovascular procedures. Angiographic findings such as total ICA occlusion at the origin with stump, ample collateral flow except in the circle of Willis, and/or calcified lesions were considered to be indicative of chronic or atherothrombotic occlusion.

Methods for Proximal Flow Blockade

Manual Compression (Guiding Catheter) Cases (March 2003 to February 2004). After insertion a 6F ultralong sheath (Shuttle, Cook, Bloomington, Ind) with an inner diameter of 0.087 inches, into the ICA, the common carotid artery or ICA was compressed by an assistant's hand to interrupt antegrade flow, to prevent migration of clots or clot fragments, and to facilitate their aspiration during clot removal. We changed the method of proximal flow blockade from manual compression to balloon guide catheter because of lack of success and radiation exposure of assistants.

Balloon Guide Catheter Cases (Since March 2004). A 9F balloon guide catheter (Patlive) with an inner diameter of 0.082 inches was used to interrupt proximal flow during clot removal.

Techniques for Clot Removal

Manual Compression. Use of a microsnare in patients with ischemic stroke was approved by the institutional ethics committee, and informed patient or proxy consent was obtained before initiation of the procedure. After a transfemoral catheterization procedure for diagnosis, a 6F ultralong sheath was advanced to the ICA ipsilateral to the occluded vessels. Accompanied by manual compression, aspiration was performed several times with a 10-mL syringe, which was chosen to avoid high negative pressure using larger syringes, to keep the vascular lumen patent, and prevent collapse during aspiration. When recanalization was not achieved by aspiration alone, microsnares (Soutenir or In-Time) were introduced through a guiding catheter. A 2.3F microcatheter (Transit 2, Cordis Endovascular, Johnson & Johnson, New Brunswick, NJ) was advanced carefully over a 0.016-inch microguidewire (GT wire, Terumo, Tokyo, Japan) across the clot in the ICA to the insular or opercular segment of the MCA. Selective angiography was performed distal to the clot to evaluate size and tortuosity of the distal arteries in which the microsnare was to be deployed. The microsnare (5 or 7 mm in diameter for Soutenir or 6 mm in diameter for In-Time) then was advanced through the microcatheter into the clot. The microsnare was manipulated in efforts to entrap the clot (Fig 1*A, -B*). Under fluoroscopic guidance, the entire microsnare and microcatheter assembly then was withdrawn completely through the guiding catheter in conjunction with temporary manual compression of the common carotid artery or the ICA.

To facilitate removal of the clot, we used an introducer with a removable valve; the presumed clot in the guiding catheter or the ICA was aspirated twice with a 10-mL syringe during manual compression. When diagnostic angiograms after removal of compression from the carotid artery showed no recanalization of the ICA, the procedure was repeated for up to 3 passes of the microsnare in an identical fashion. Unless recanalization was achieved, localized intra-arterial fibrinolysis or PTCBA subsequently was performed.

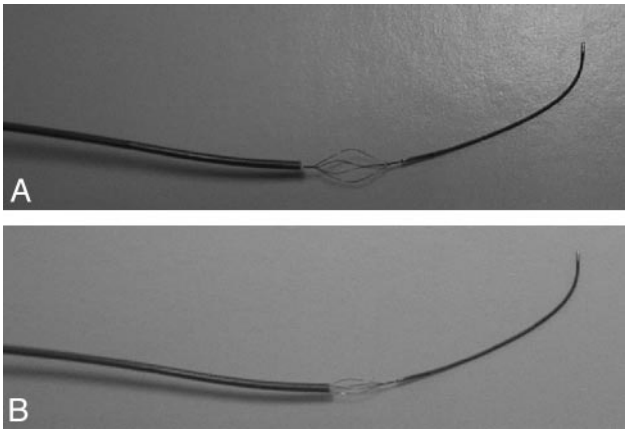

Fig 1. Photograph of the basket-type microsnare (Soutenir, 5 mm) after deployment through the 2.3F microcatheter. The fully extended basket of the microsnare is 5 mm in diameter when the microsnare is protruded completely from the microcatheter (*A*) and is closed appropriately when partially withdrawn into the microcatheter (*B*).

Balloon Guide Catheter. In cases involving proximal flow blockade with a balloon guide catheter, transfemoral catheterization was performed after placement of a 9F sheath. A 9F balloon guide catheter was placed in the ICA ipsilateral to the occluded vessels. The coaxial balloon on the guiding catheter was inflated immediately after positioning of the guiding catheter. Then the guiding catheter initially was aspirated with a 10-mL syringe; when some clot was aspirated, the procedure was repeated in an identical fashion until successful removal of a large amount of clot. When no clot or fewer clots were aspirated, the microcatheter or microsnare was advanced to the lesion and the entire microsnare and microcatheter assembly was withdrawn completely through the guiding catheter during inflation of the balloon. After withdrawal of the microsnare, the presumed clot in the guiding catheter or ICA was aspirated twice with a 10-mL syringe during proximal ICA blockade. When a large amount of clot was removed, brisk backflow through the guiding catheter was evident. Then a small volume of contrast medium was injected slowly through the balloon guide catheter during proximal ICA blockade. When flow reversal of contrast medium was seen angiographically, suggesting recanalization of the ICA, the coaxial balloon on the guiding catheter was deflated and carotid angiography was performed to confirm recanalization of the ICA.

Systemic anticoagulation was provided by intra-arterial administration of a bolus of heparin (5000 U) via the introducing sheath just after inserting it into the artery to maintain an activated clotting time of >250 seconds during the procedure.

Management After Clot Removal Therapy

After the procedure, each patient was monitored closely in the intensive care unit for 24 hours with strict blood pressure control. Cranial CT was performed immediately and at 24 hours, 7 days, and 90 days after completion of the procedure. All patients received intravenous edaravone,[26] a free-radical scavenger, at a dose of 30 mg twice daily. Heparin therapy (10 000 U/day) was continued after ruling out intracranial hemorrhage in the 24-hour CT.

Outcome Measures and Statistical Analysis

Pertinent medical records and imaging studies were reviewed for all 14 patients who underwent clot removal therapy. Radiographic outcome immediately after the procedure (ie, complete, partial, or no recanalization), neurologic outcome at 7 days (NIHSS score), func-

Table 1: Patient information

Patient No./ Sex/Age (y)	Clinical Symptoms on Admission	NIHSS Score on Admission	Treatment before Procedure	Onset-to-Procedure Time (min)	Embolic Risk Factor
1/M/82	Somnolence, TA, HP	18	None	116	AF
2/M/81	Somnolence, AG, HP	21	None	349	AF
3/M/91	Stupor, AG, CD, HP	19	None	209	AF
4/F/78	Coma, TA, QP	26	None	120	AF
5/M/88	Somnolence, AG, CD, HP	17	None	173	AF
6/M/88	Coma, TA, HP	24	None	137	AF
7/F/87	Somnolence, TA, CD, HP	22	None	223	AF
8/M/78	Stupor, AG, CD, HP	19	Warfarin	230	AF
9/M/64	Somnolence, AG, HP	14	Aspirin	152	AF
10/F/32	Stupor, TA, CD, HP	24	Heparin + warfarin	123	DCM
11/M/73	Somnolence, TA, CD, HP	18	Heparin + warfarin	98	AF
12/F/81	Somnolence, TA, CD, HP	21	None	193	AF
13/F/69	Somnolence, TA, HP	17	None	310	AF
14/F/73	Somnolence, AG, CD, HP	21	Aspirin	195	AF

Note:—NIHSS indicates National Institutes of Health Stroke Scale; TA, total aphasia; HP, hemiplegia/hemiparesis; AG, agnosia; CD, conjugate deviation of the eyes; QP, quadriparesis; AF, atrial fibrillation; DCM, dilated cardiomyopathy.

Table 2: Preprocedure MR findings

Patient No./ Sex/Age (y)	Side of Lesion	High Signal Intensity on DWI		Delay in MTT	Relative CBV	Diffusion/Perfusion Mismatch
1/M/82	L	CF, BG	Small abnormality	Yes	Large signal intensity loss	Large
2/M/81	R	BG	Small abnormality	Yes	Small signal intensity loss	Small
3/M/91	R	CF, BG	Small abnormality	Yes	Small signal intensity loss	Small
4/F/78	L	IC	Small abnormality	Yes	Large signal intensity loss	Large
5/M/88	R	CF, IC, BG	Small abnormality	Yes	Large signal intensity loss	Large
6/M/88	L	None	Normal	Yes	Large signal intensity loss	Large
7/F/87	L	BG	Small abnormality	Yes	Large signal intensity loss	Large
8/M/78	R	BG	Small abnormality	Yes	Large signal intensity loss	Large
9/M/64	R	BG	Small abnormality	Yes	Small signal intensity loss	Small
10/F/32	L	NEIS	NA	NA	NA	NA
11/M/73	L	CF, IC	Small abnormality	Yes	Large signal intensity loss	Large
12/F/81	L	CF, CP, BG	Small abnormality	Yes	Large signal intensity loss	Large
13/F/69	L	CF, BG	Small abnormality	Yes	Large signal intensity loss	Large
14/F/73	R	None	Normal	Yes	Small signal intensity loss	Large

Note:—DWI indicates diffusion weighted image; MTT, mean transit time; CBV, cerebral blood volume; CF, cortex of the frontal lobe; IC, insular cortex; BG, basal ganglia; CP, cortex of the parietal lobe; NEIS, no early ischemic sign on cranial computed tomography; NA, not available.

tional outcome at 90 days (modified Rankin Scale [mRS]), incidence of procedure-related complications, and symptomatic intracranial hemorrhage diagnosed by cranial CT all were analyzed. Complete recanalization was defined angiographically as normal opacification of all occluded arteries. Partial recanalization was defined as recanalization of some but not all of the occluded arteries. Neurologic outcome at 7 days was considered favorable when the NIHSS score had improved by 5 points or more from the baseline NIHSS score. Functional outcome at 90 days was evaluated in the outpatient clinic and considered favorable if mRS was 0–2. In patients with severe disability (mRS, 4 or 5) or death, the patient's family was interviewed. Procedure-related complications, defined as vessel perforation, arterial dissection, or embolization to a previously uninvolved territory, were diagnosed by angiography or cranial CT immediately after the procedure. Intracranial hemorrhage involving hemorrhagic transformation as determined by cranial CT was considered symptomatic if associated with clinical deterioration of 5 points or more on the NIHSS score.

Numbers of patients with favorable neurologic outcome at 7 days and with favorable functional outcome at 90 days were compared with Fisher exact test between 2 groups, partial/complete and no recanalization. A P value of <0.05 was considered to indicate statistical significance. SPSS software (version 9.0, SPSS Inc, Chicago, Ill) was used to perform statistical analyses.

Results

Among 14 patients who underwent clot removal therapy, 8 were men and 6 were women; ages ranged from 32 to 91 years. Median baseline NIHSS score was 20 (range, 14–26). An anticoagulant already had been prescribed before the procedure in 3 patients. Median elapsed time from onset to clot removal therapy was 183 minutes (range, 98–349 minutes; Table 1). Preprocedure DWI detected small or no acute infarction as well as perfusion/diffusion mismatch in all patients except 1 (case 10), who could not undergo DWI because of periodic adjustment of the MR imaging equipment (Table 2). Conventional angiograms confirmed total occlusion of the ICA in all patients. Retrieval devices were used in 10 patients: in 2 patients (cases 4 and 11), retrieval devices could not be deployed in the peripheral artery distal to the occlusion site because the microguidewire could not penetrate the clot; in 2 other patients (cases 9 and 14), complete recanalization was achieved simply with aspiration through the guiding catheter and no retrieval device was required. In 10 of 14 patients, a balloon guide catheter was used to interrupt blood flow during clot removal by aspiration or retrieval instrumentation. Additional therapy with PTCBA was performed in 8 patients; one of them (case 2) underwent localized intra-arterial fibrinolysis simultaneously (Table 3).

Table 3: Preprocedure angiographic findings and devices used for CRT

Patient No./ Sex/Age (y)	Occluded Vessel	Retrieval Devices	Proximal Flow Blockade	Additional Therapy	Dose of Urokinase
1/M/82	ICA (C3)	Soutenir	MC	PTCBA	0
2/M/81	ICA (C1)	Soutenir	MC	PTCBA, LIF	30*
3/M/91	ICA (C7)	Soutenir	MC	PTCBA	0
4/F/78	ICA (C6)	No device	MC	No	0
5/M/88	ICA (C6)	In-Time	BGC	PTCBA	0
6/M/88	ICA (C1)	Soutenir	BGC	PTCBA	0
7/F/87	ICA (C3)	In-Time	BGC	No	0
8/M/78	ICA (C7)	Soutenir	BGC	No	0
9/M/64	ICA (C1)	No device	BGC	No	0
10/F/32	ICA (C7)	Soutenir	BGC	PTCBA	0
11/M/73	ICA (C7)	No device	BGC	No	0
12/F/81	ICA (C7)	Soutenir	BGC	PTCBA	0
13/F/69	ICA (C7)	Soutenir	BGC	PTCBA	0
14/F/73	ICA (C3)	No device	BGC	No	9

Note:—CRT indicates clot removal therapy; ICA, internal carotid artery; C1, carotid segment; C3, lacerum segment; C6, ophthalmic segment; C7, terminal segment; MC, manual compression; BGC, balloon guide catheter; PTCBA, percutaneous transluminal cerebral balloon angioplasty; LIF, localized intra-arterial fibrinolysis.
* $\times 10^4$ units.

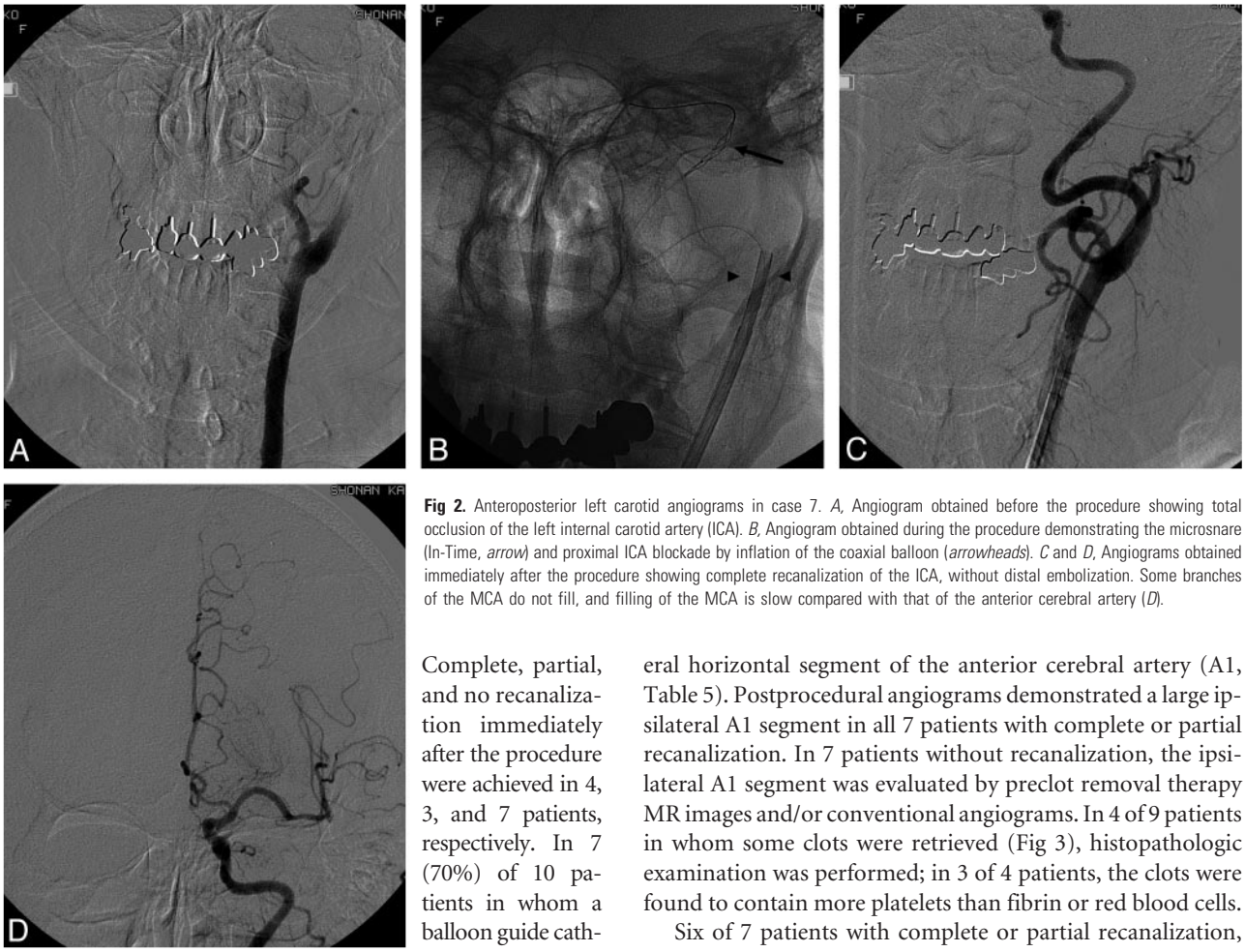

Fig 2. Anteroposterior left carotid angiograms in case 7. *A,* Angiogram obtained before the procedure showing total occlusion of the left internal carotid artery (ICA). *B,* Angiogram obtained during the procedure demonstrating the microsnare (In-Time, *arrow*) and proximal ICA blockade by inflation of the coaxial balloon (*arrowheads*). *C* and *D,* Angiograms obtained immediately after the procedure showing complete recanalization of the ICA, without distal embolization. Some branches of the MCA do not fill, and filling of the MCA is slow compared with that of the anterior cerebral artery (*D*).

Complete, partial, and no recanalization immediately after the procedure were achieved in 4, 3, and 7 patients, respectively. In 7 (70%) of 10 patients in whom a balloon guide catheter was used to interrupt proximal flow during clot removal, complete or partial recanalization was achieved; case 7 is illustrative (Fig 2*A–D*). None of the 4 patients with manual compression obtained recanalization. In 8 patients without complete recanalization, additional PTCBA or localized intra-arterial fibrinolysis failed to further recanalize the occluded vessel (Table 4). Angiographic results immediately after clot removal therapy were dichotomized, according to methods of proximal flow blockade and anatomic features of the ipsilateral horizontal segment of the anterior cerebral artery (A1, Table 5). Postprocedural angiograms demonstrated a large ipsilateral A1 segment in all 7 patients with complete or partial recanalization. In 7 patients without recanalization, the ipsilateral A1 segment was evaluated by preclot removal therapy MR images and/or conventional angiograms. In 4 of 9 patients in whom some clots were retrieved (Fig 3), histopathologic examination was performed; in 3 of 4 patients, the clots were found to contain more platelets than fibrin or red blood cells.

Six of 7 patients with complete or partial recanalization, but only 1 of 7 patients with no recanalization, had a favorable neurologic outcome at 7 days ($P < .05$). Six of 7 patients with complete or partial recanalization, but none with no recanalization, had a favorable functional outcome ($P < .01$, Table 6). A procedure-related complication in 1 patient (case 12, Table 6) was distal embolism of probable clot fragment into a peripheral branch of the ipsilateral anterior cerebral artery, representing previously uninvolved territory. Fortunately, the embolism did not influence neurologic symptoms; however,

Table 4: Postprocedure findings

Patient No./ Sex/Age (y)	Angiographic Result	Retrieved Clot	Clot Captured with Snare	Histologic Findings	Procedure Time (min)*	CT findings 24 h after Procedure
1/M/82	No recanalization	Yes	No	NE	42	LLA
2/M/81	No recanalization	No	No	NE	101	LLA
3/M/91	No recanalization	Yes	Yes	NE	103	SLA (SCI), SHA
4/F/78	No recanalization	No	No	NE	50	LLA
5/M/88	No recanalization	Yes	No	NE	104	LLA
6/M/88	No recanalization	No	No	NE	65	LLA
7/F/87	Complete recanalization	Yes	No	NE	81	SLA (SCI)
8/M/78	Complete recanalization	Yes	Yes	NE	45	SLA (SCI)
9/M/64	Complete recanalization	Yes	No	PRC	43	SLA (SCI)
10/F/32	Partial recanalization	Yes	Yes	PRC	97	SLA (SCI), SHA
11/M/73	No recanalization	No	No	NE	87	LLA, SHA
12/F/81	Partial recanalization	Yes	No	PRC	61	LLA
13/F/69	Partial recanalization	No	No	NE	55	SLA (SCI), LLA
14/F/73	Complete recanalization	Yes	No	FRC	40	SLA

Note:—NE indicates no examination; PRC, platelet-rich clot; FRC, fibrin-rich clot; CT, computed tomography; LLA, large low-attenuation area; SLA, small low-attenuation area; SHA, small high-attenuation area; SCI, striatocapsular infarction.
* Time for obtaining an angiographic diagnosis and completing the procedure.

Table 5: Methods of PFB and anatomic feature versus angiographic results

		Angiographic Results		
Methods of PFB	Anatomic Feature*	Complete Recanalization	Partial Recanalization	No Recanalization
Balloon guide catheter	Ipsilateral A1			
	Large	4	3	1
	Small/none	0	0	2
Manual compression	Ipsilateral A1			
	Large	0	0	1
	Small/none	0	0	3

Note:—PFB indicates proximal flow blockade; A1, horizontal segment of the anterior cerebral artery.
* Diagnosed by pre- or postprocedure magnetic resonance angiography or cerebral angiography.

cerebral infarction occurred in the extensive territory of the nonrecanalized MCA. No perforation or dissection was seen in any artery by angiography immediately after the procedure. CT, immediately after the procedure, showed neither intracranial hemorrhage nor subarachnoid hemorrhage in any patient, and CT at 24 hours and at 7 days after completion of the procedure detected no symptomatic intracranial hemorrhage (Table 4).

Discussion

The present study shows that clot removal therapy by using a balloon guide catheter can be practiced safely to obtain a high recanalization rate and improve neurologic outcome at 7 days and functional outcome at 90 days in patients with embolic ICA occlusion. Only 1 patient among 14 had a procedural complication, a distal embolization into a small branch of the ipsilateral anterior cerebral artery, which did not influence neurologic symptoms. Of 10 patients in whom a balloon guide catheter was used for proximal flow blockade, complete or partial recanalization was obtained in 7 (70%, Table 5). Of the 7 patients so revascularized, 6 had favorable neurologic and functional outcomes, whereas the 4 patients treated with manual compression rather than balloon occlusion obtained no recanalization and had poor neurologic and functional outcomes. No symptomatic intracranial hemorrhages occurred in the 14 patients.

Benefits of clot removal therapy by using a microsnare in acute ischemic stroke have been reported anecdotally in previous studies.[10-17] Recently, a device used for mechanical clot extraction (Merci Retriever, Concentric Medical, Mountain View, Calif) was reported to be beneficial in treatment of patients with embolic stroke[18-20]; in August 2004, the United States Food and Drug Administration approved the device for treatment of patients with ischemic stroke. Although the microsnare was designed to entrap rather than disrupt intravascular obstacles (in this case, clots), it captured only some small clots in 3 of 14 of our patients; the bulk of the clots ultimately was aspirated through the guiding catheter. Moreover, in the present study, we found that successful recanalization de-

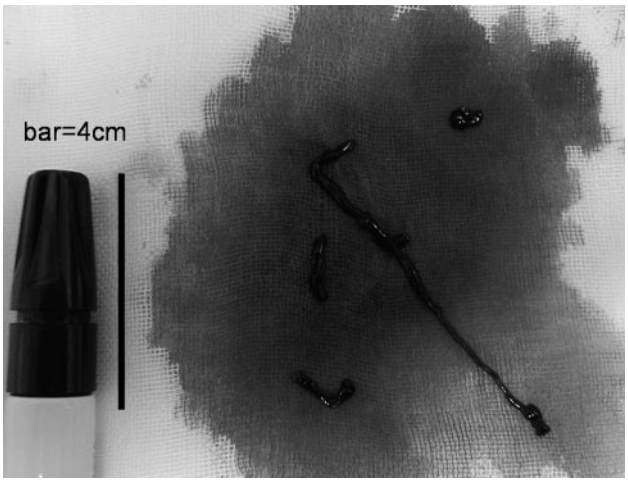

Fig 3. Macroscopic photograph showing the 4 clots retrieved in case 7. The extent of the longest clot is >7 cm.

Table 6: Clinical results

Patient No./ Sex/Age (y)	Angiographic Result	NIHSS Score		Favorable Neurologic Outcome*	mRS Score at 90 d after Procedure	Procedure-related Complication
		On Admission	At 7 d after Procedure			
1/M/82	No recanalization	18	16	No	4	None
2/M/81	No recanalization	21	15	Yes	5	None
3/M/91	No recanalization	19	15	No	5	None
4/F/78	No recanalization	26	42	No	6	None
5/M/88	No recanalization	17	23	No	5	None
6/M/88	No recanalization	24	24	No	5	None
7/F/87	Complete recanalization	22	6	Yes	1	None
8/M/78	Complete recanalization	19	2	Yes	0	None
9/M/64	Complete recanalization	14	5	Yes	1	None
10/F/32	Partial reacanalization	24	12	Yes	2	None
11/M/73	No recanalization	18	14	No	4	None
12/F/81	Partial recanalization	21	42	No	6	Distal embolism†
13/F/69	Partial recanalization	17	9	Yes	2	None
14/F/73	Complete recanalization	21	4	Yes	1	None

Note:—NIHSS indicates National Institutes of Health Stroke Scale; mRS, modified Rankin Scale.
* NIHSS scores at 7 days after procedure compared with baseline improved 5 or more points.
† Distal embolism to a small branch of the ipsilateral anterior cerebral artery.

pended on proximal ICA flow blockade with a balloon guide catheter (as opposed to manual compression) to support retrieval of the clots and to avoid migration of entrapped or disrupted clots; this technique first was reported by Mayer et al,[13] who used it to treat basilar artery embolism.

On the other hand, the success rate of transarterial suction thrombectomy by using a guiding catheter[22,23] reportedly may increase when clots are retracted from the terminal ICA to the proximal ICA by a microsnare. Qureshi et al[21] reported efficacy of microsnares in mechanical disruption of clots for treatment of patients with acute ischemic stroke. Although successful clot removal was achieved by aspiration through a balloon guide catheter, we believe that the microsnares may have facilitated aspiration by retracting the clots toward the guiding catheter and/or by fragmenting the clots.

In 7 patients with complete or partial recanalization, angiograms immediately after the procedure revealed a well-developed ipsilateral A1 segment. In retrospect, crossflow via the A1 segment facilitated aspiration of the clots embedded in the ICA into the guiding catheter lumen, though until recanalization of the ICA, the degree of development of the ipsilateral A1 segment is difficult to judge. On the other hand, ample ipsilateral flow via the posterior communicating artery was demonstrated by angiography immediately after the procedure in 3 of 7 patients with complete or partial recanalization. Ample flow from the well-developed posterior communicating artery may interfere with clot removal by aspiration and extraction in case clots are embedded in the ICA distal to the posterior communicating artery. However, no apparent relationship was found between development of the posterior communicating artery and successful recanalization in the present study. We assume that the anterior communicating artery facilitates clot retrieval, whereas the well-developed posterior communicating artery may disturb it in the case of clots embedded in the terminal ICA.

One advantage of clot removal therapy is the potential ability to retrieve some large or partially organized firm clots that rarely can be disrupted by pharmacologic thrombolysis or PTCBA alone, though our histologic findings in retrieved clots indicated fresh, not organized, thrombi. The other potential advantage of clot removal therapy is the ability to obtain rapid recanalization. In 4 patients with complete recanalization in the present study, no additional treatment was required to recanalize distal branch occlusion; in these patients, the median time from obtaining an angiographic diagnosis to completing the procedure was 44 minutes (range, 40–81 minutes), an interval somewhat longer than times reported by Wikholm[16] because of the time required to establish the proximal flow blockade with the balloon. Another potential advantage of clot removal therapy is a theoretically lower risk of symptomatic intracranial hemorrhage because lytic agents are avoided or only minimally used; this may expand the therapeutic time window for recanalization. In fact, clot removal therapy was performed within 8 hours of symptom onset in the MERCI study.[18,20]

On the other hand, a potential disadvantage of clot removal therapy is clot fragmentation, leading to distal embolization. Proximal flow blockade by the balloon guide catheter and use of sufficient suction appeared important for avoiding distal embolization during retraction of clot. However, proximal flow blockade by the balloon guide catheter cannot always completely prevent distal embolization because crossflow via the A1 segment or the posterior communicating artery may propel some clots into the peripheral MCA and/or anterior cerebral artery. Moreover, when to deflate the balloon is not easy to determine; if deflation is too early, distal embolization of clot fragments may occur in the anterior cerebral artery (case 12), MCA, or both. Other potential complications of clot removal therapy are vessel perforation, arterial dissection, or spasm.

To minimize these risks, we believe that careful and gentle catheter manipulation is essential, and the microcatheter should be navigated up to the distal portion of the clot before deploying the microsnare. Avoidance of vessel injury was confirmed, in part, by histologic absence of endothelial cells in our clot specimens. Although patients with acute stroke with atherothrombotic or dissecting occlusion were excluded from clot removal therapy in the present study, excluding all such patients with certainty is impossible. If atherothrombotic or dissecting occlusion becomes suspected after clot removal

therapy, additional PTCBA or stent placement should be performed immediately after the procedure. The microsnare used in the present study was a stainless steel basket designed not to entrap clots but to grasp various foreign objects. Specifically designed microsnares should be developed for clot removal therapy to capture or retrieve clots more successfully.

Although risks and benefits of clot removal therapy in the treatment of acute embolic stroke were not completely established in this small retrospective study, our results suggest that clot removal therapy by using a balloon guide catheter is feasible, safe, and effective in the treatment of patients with acute embolic occlusion of the ICA and should prompt clinical trials in larger numbers of patients.

Conclusion

Our results suggest that clot removal therapy in conjunction with temporary proximal ICA occlusion by a balloon guide catheter can be practiced safely for treating acute embolic ICA occlusion. A high recanalization rate was attained in patients with anatomic crossflow, and 7-day neurologic status and 90-day functional outcome were improved.

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