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Original Article

Angiographical Features of Acute Stroke Patients with Carotid Artery Embolic Occlusion Recanalized by Suction with Syringe via Balloon Guiding Catheter

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Objective: This study was conducted to clarify the characteristics of preprocedural vascular images in patients with acute embolic occlusion of the carotid artery in whom the internal carotid artery (ICA) could be recanalized by manual suction with syringe via the balloon guiding catheter (SS-BGC) alone.

Methods: The subjects were 64 consecutive patients who underwent SS-BGC for carotid artery embolic occlusion at our institution between May 2006 and September 2017. The subjects were classified into those who with recanalization (R-SS-BGC group) and no recanalization (N-SS-BGC) of ICA by SS-BGC alone, and the background factors including findings of preprocedural vascular imaging and outcomes were compared between the two groups.

Results: The R-SS-BGC and N-SS-BGC groups consisted of 16 and 48 patients, respectively. In the R-SS-BGC/N-SS-BGC groups, the horizontal segment of the ipsilateral anterior cerebral artery (A1) was patent in 15/24 (94/50%) and the horizontal segment of the ipsilateral middle cerebral artery (M1) was patent in 6/16 (38/34%) on preprocedural MRA. The ipsilateral posterior communicating artery (PcomA) was patent in 3/14 (19/29%) and the ipsilateral ophthalmic artery (OphA) was patent in 1/14 (6/29%) on preprocedural angiography. The median duration of operation was 39/86.5 minutes, and complete recanalization could be achieved in 15/34 (94/71%). The outcome was favorable in 10/11 (63/23%).

Conclusion: In the R-SS-BGC group, the percentages of patients with patent ipsilateral A1 and M1 were high, and the percentages of those with patent ipsilateral PcomA and OphA were low.

Keywords acute stroke, carotid artery embolic occlusion, recanalization, syringe-suction, balloon guiding catheter

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Introduction

For thrombectomy in acute cerebral infarction, procedures using the stent-retriever, which is a thrombectomy device, are regarded as the first-line treatment according to the results of randomized controlled studies conducted overseas.[1)] The Japanese guideline also recommends thrombectomy using the stent-retriever as grade A.[2)] To obtain a favorable outcome, the importance of shortening the time until recanalization is emphasized.[3)] At our institution, we first attempt manual suction via a syringe with the balloon guiding catheter (SS-BGC) attached to the Y connector before the use of a clot-retrieval device for thrombectomy of acute embolic occlusion of the carotid artery to shorten the time until recanalization. The aim of this study was to evaluate the characteristics of preprocedural vascular images in patients with acute embolic occlusion of the carotid artery in whom the internal carotid artery (ICA) could be recanalized by SS-BGC alone.

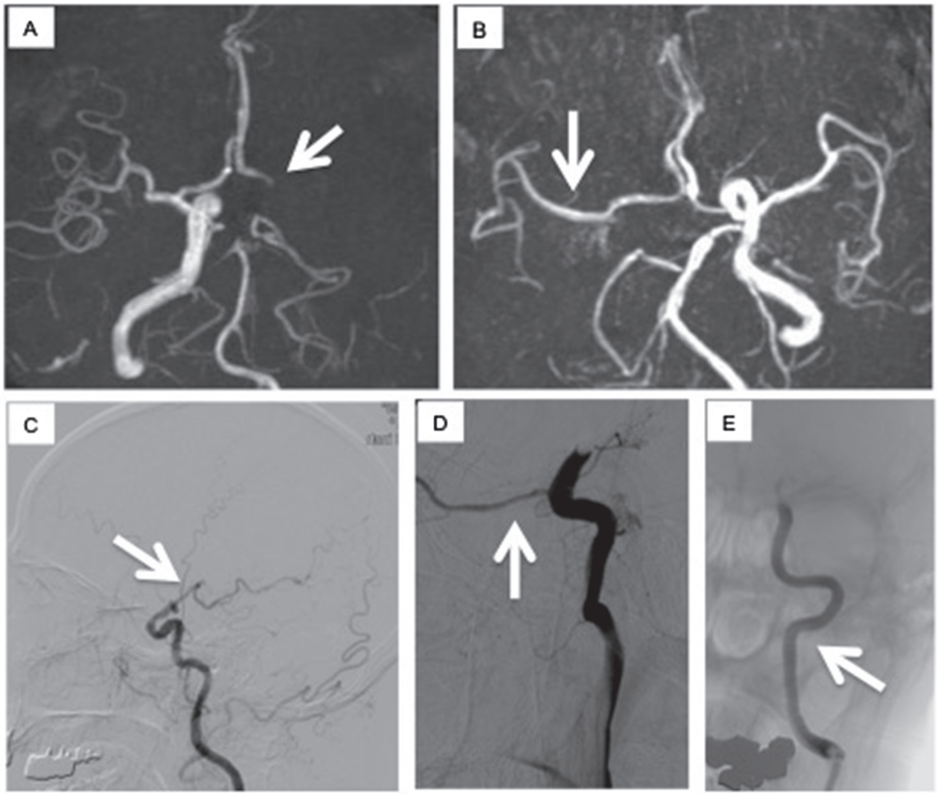

Fig. 1 Preprocedural MRA and angiograms. (**A**) Case with ipsilateral patent A1; (**B**) case with ipsilateral patent M1, which is patent MCA type; (**C**) case with ipsilateral patent PcomA; (**D**) case with ipsilateral patent OphA; and (**E**), case with kinking of ipsilateral cervical segment of the ICA. ICA: internal carotid artery; MCA: middle cerebral artery; OphA: ophthalmic artery; PcomA: posterior communicating artery

Materials and Methods

Of the 127 consecutive patients with cerebral infarction who underwent emergent recanalization for acute occlusion of the carotid artery at our institution between May 2006 and September 2017, 55 with atherosclerotic/arterial dissection lesions, 5 in whom the BGC was difficult to place in the common carotid artery (CCA), 1 in whom the BGC was not used, 1 with bilateral ICA occlusion, and 1 in whom the lesion was partially recanalized before the procedure was excluded, and 64 with acute embolic occlusion of the carotid artery (3 with CCA occlusion and 61 with ICA occlusion) were evaluated as the subjects. They were classified into those in whom the ICA could be recanalized by SS-BGC alone (recanalization-SS-BGC [R-SS-BGC] group) and those in whom the ICA could not be recanalized by SS-BGC alone and additional procedures were necessary (no recanalization-SS-BGC [N-SS-BGC] group), and the background factors including preprocedural MRA and angiographical findings, contents of the procedures, and outcomes were compared between the two groups.

As background factors, the age, sex, past history, National Institutes of Health Stroke Scale (NIHSS) and Alberta Stroke Program Early CT Score (ASPECTS) at arrival, onset-to-door time (O2DT), and door-to-puncture time (D2PT) were evaluated. Concerning the findings of preprocedural vascular imaging, the patency of the horizontal segment (A1) of the anterior cerebral artery (ACA) ipsilateral to the occluded ICA, patency of the horizontal portion (M1) of the ipsilateral middle cerebral artery (MCA), and patency of the ipsilateral A1 and M1 (so-called patent MCA type) on preprocedural MRA, as well as the patency of the large ipsilateral posterior communicating artery (PcomA), patency of the large ipsilateral ophthalmic artery (OphA), and tortuosity and stenosis of the ipsilateral cervical ICA on intraoperative angiography were evaluated. The ICA was judged to be tortuous when it curved more sharply than 90° and to be stenosed when the stenosis rate was ≥60%. **Figure 1** shows the typical findings on preprocedural imaging. Head MRA and angiographic findings were interpreted by two specialists in neuroendovascular treatment.

Concerning the contents of procedures, along with the use of intravenous thrombolysis with tissue plasminogen activator (t-PA) or other catheter techniques, whether clots were retrieved or not by SS-BGC, presence or absence of the occurrence of backflow immediately after inflation of the coaxial balloon of the BGC, and time spent on SS-BGC (sec) were evaluated.

As for the outcomes, patients in whom thrombolysis in cerebral infarction (TICI) 2b or better recanalization was achieved, duration of treatment (time from puncture to the end of the procedure with TICI 2B or better recanalization [P2RT]), patients with severe treatment-related complications, patients with symptomatic intracranial hemorrhage (accompanied by exacerbation of NIHSS ≥4), patients with a favorable outcome after 3 months (modified Rankin Scale [mRs] 0-2), and patients who died within 90 days were investigated. Migration of clots to the ACA or MCA that were patent intraoperatively (embolization to new territory [ENT]) and migration of clots from proximal to distal portion of the MCA (embolization to distal territory [EDT]), as well as vascular damage at puncture/approach and treatment-associated intradural vascular damage (extravasation, subarachnoid hemorrhage, brain hemorrhage) were included in severe treatment-related complications, but asymptomatic subarachnoid hemorrhage was not. Concerning statistical analysis, continuous and categorical variables were examined using the t-test and chi-square test, respectively, and $P < 0.05$ was regarded as significant. This study was carried out with approval by the institutional review board of our hospital (Approval No. 739).

Protocol of SS-BGC at our facility

A 9 Fr/25 cm sheath is placed in the right femoral artery, and, using a combination of a 5F/125 cm coaxial catheter and balloon guide catheter (BGC; Optimo 9Fr/90 cm, Tokai Medical Products, Aichi, Japan; FlowGate 2 8F/95 cm, Stryker, Fremont, CA, USA), diagnostic imaging is performed once after the coaxial catheter is elevated to the CCA of the affected side. Then, the BGC is navigated to a proximal portion of the CCA if the CCA is occluded and to the cervical ICA if the ICA is occluded. Then, the coaxial balloon of the BGC is inflated, the Y connector of the BGC is connected to a 10-mL syringe, and manual aspiration is performed. If backflow is observed from the Y connector or hub of the BGC, additional aspiration was made until residual clots disappeared from the blood in the syringe. And then the coaxial balloon is deflated and angiography is performed. If no backflow is observed from the hub of the BGC after multiple attempts of SS-BGC, the procedure is changed to one using a thrombectomy device such as the stent-retriever or Penumbra system (Penumbra, Alameda, CA, USA). The subjects of this study included patients treated using Patlive 9Fr/90 cm (Terumo Clinical Supply, Tokyo, Japan) or Merci retriever (Stryker).

Representative case of R-SS-BGC group (Fig. 2)

A 76-year-old male was emergently transported due to disturbance of consciousness, global aphasia, left concomitant deviation, and right hemiplegia (NIHSS: 25, O2DT: 21 min). Diffusion-weighted MRI of the head showed high signal intensity areas in the left putamen, insular cortex, and corona radiata (ASPECTS: 8; **Fig. 2A** and **2B**), and MRA of the head confirmed signal defect in the left ICA and MCA and signal persistence in the ipsilateral A1 (**Fig. 2C**). The patient was transferred to the angiography suite while administering intravenous t-PA, and the right femoral artery was punctured (D2PT: 59 min). We confirmed that the contrast medium did not flow distally to the left cervical ICA by angiography via the coaxial catheter advanced to the CCA and judged non-patency of the ipsilateral OphA and PcomA (**Fig. 2D–2E**). North American Symptomatic Carotid Endarterectomy Trial (NASCET) 55% stenosis was noted at the origin of the ICA, but as the patient exhibited atrial fibrillation, a diagnosis of cardiogenic cerebral embolism was made. Next, the BGC was advanced to the origin of the left cervical ICA, the coaxial balloon was inflated, and SS-BGC was initiated (**Fig. 2F**). Nothing could be aspirated immediately after the beginning due to the development of negative pressure, but the aspiration of blood into the syringe began to be observed after a few seconds, backflow from the hub side of the BGC also appeared, and hard clots were retrieved in the syringe (**Fig. 2G**). After aspiration was continued until clots disappeared from the blood, the coaxial balloon was deflated. By confirming TICI 3 complete recanalization by angiography via the BGC, the procedure was ended (**Fig. 2H** and **2I**; P2RT: 13 min). Postprocedural CT of the head showed no intracranial hemorrhage, and the mRS after 3 months was 1.

Results

The R-SS-BGC and N-SS-BGC groups consisted of 16 (25% of those who received SS-BGC) and 48 patients, respectively. Regarding the background factors, O2DT was significantly shorter in the R-SS-BGC group than in the N-SS-BGC group (**Table 1**). Concerning the findings of

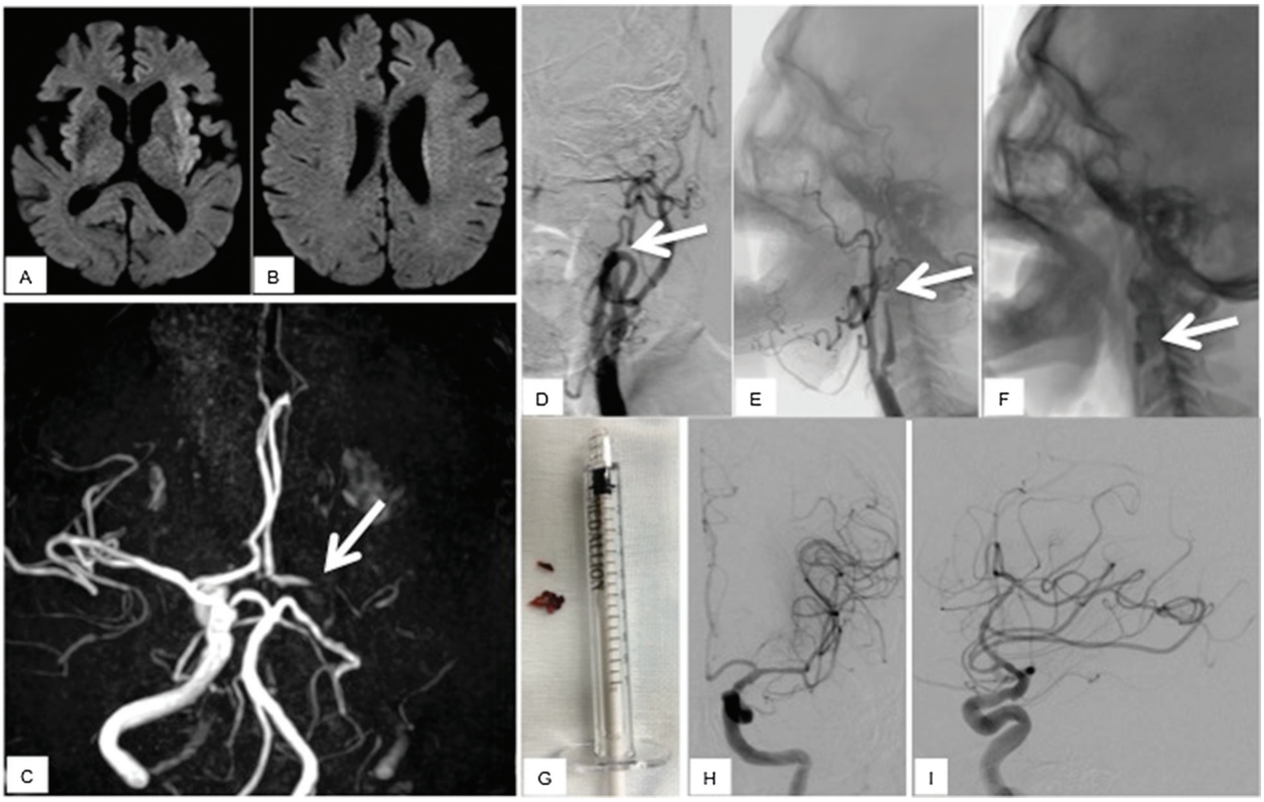

Fig. 2 Representative case of R-SS-BGC group. Pre-procedural diffusion-weighted MRI showed signal high intensity in the left putamen, insular cortex, and corona radiata (**A** and **B**). MR angiography revealed occlusion of the left ICA with patency of the ipsilateral A1 (**C**). Digital subtraction angiography demonstrated occlusion of the left ICA with limited filling of contrast media into the cervical portion (**D**) antero-posterior view; (**E**) lateral view. BGC was proceeded to the origin of the ICA, in which coaxial balloon was inflated (**F**) lateral view followed immediately by manual suction with 10-mL syringe. After solid thrombi were aspirated (**G**) and backflow from the guiding catheter hub was seen, complete recanalization of the distal vessels involving the ICA was confirmed (**H**) antero-posterior view; (**I**) lateral view. BGC: balloon guiding catheter; ICA: internal carotid artery; R-SS-BGC: recanalization-manual suction with syringe via the balloon guiding catheter

preprocedural vascular imaging, the percentage of patients with patent ipsilateral A1 on preprocedural MRA was significantly higher and the percentages of those with patent MCA and patent ipsilateral M1 were also relatively higher in the R-SS-BGC group than in the N-SS-BGC group (**Table 1**). In the R-SS-BGC group, on the other hand, the percentages of those with patent ipsilateral PcomA and those with patent ipsilateral OphA were lower and tortuosity of the carotid artery to the site of occlusion was less on intraoperative cerebral angiography (**Table 1**). Regarding the contents of treatment, retrieved clots in the syringe, Y-connecter or hub were confirmed significantly more frequently, backflow immediately after inflation of the coaxial balloon was observed less frequently, and time spent on SS-BGC was shorter, in the R-SS-BGC group (**Table 2**). As for the outcomes in the R-SS-BGC group, the percentage of patients in whom TICI 2b or better recanalization could be achieved was higher, P2RT was significantly shorter, and the percentage of patients with a favorable outcome was significantly higher. No difference was observed in severe treatment-related complications between the two groups (**Table 2**).

In this study, also, the predictive score for efficacy of SS-BGC (PSESS-BGC) was calculated by giving 2 points to patency of the ipsilateral A1 (a factor that showed a significant difference), 1 point to patency of the ipsilateral M1, −1 point to patency of the ipsilateral PcomA or ipsilateral OphA, −1 point to tortuousness of the ipsilateral carotid artery, and summing up the points (**Table 3**). The PSESS-BGC was ≥1 in 14 (87.5%) of the 16 patients in the R-SS-BGC group and 12 (43.8%) of the 48 patients in the N-SS-BGC group with a significant difference in frequency ($p < 0.001$).

Cases 1, 2, 3, 4, 9, and 11 in **Table 3** were the patent MCA type.

Discussion

In revascularization therapy for acute cerebral infarction, thrombectomy using a clot-retrieval device is the mainstay

Table 1 Backgrounds involving MRA and angiographical findings

	R-SS-BGC group (n = 16)	N-SS-BGC group (n = 48)	Odds ratio (95% CI)	P value
Age, yr, median (SD)	74 (6.9)	80 (10.7)		0.45
Male, no. (%)	8 (50.0)	22 (45.8)	1.18 (0.38–3.67)	0.77
Smoking, no. (%)	3 (18.7)	10 (21.3)	0.85 (0.20–3.59)	0.82
Alcohol, no. (%)	6 (37.5)	11 (23.4)	1.96 (0.58–6.63)	0.27
Hypertension, no. (%)	10 (62.5)	35 (74.3)	0.57 (0.17–1.91)	0.36
Diabetes, no. (%)	3 (18.8)	8 (17.0)	1.17 (0.26–4.88)	0.87
Hyperlipidemia, no. (%)	4 (25.0)	15 (31.9)	0.71 (0.19–2.58)	0.6
Ischemic heart disease, no. (%)	2 (12.5)	7 (15.0)	0.82 (0.15–4.40)	0.81
Arteriosclerosis obliterans, no. (%)	1 (8.3)	1 (1.8)	3.36 (0.18–52.0)	0.41
Atrial fibrillation, no. (%)	15 (93.8)	36 (76.6)	4.58 (0.54–38.7)	0.13
Chronic kidney disease, no. (%)	6 (37.5)	14 (29.8)	0.14 (0.43–4.64)	0.56
Dialysis, no. (%)	2 (12.5)	2 (4.17)	3.29 (0.42–25.5)	0.23
Blood sugar level, median (interquartile range)	116 (103–168)	139 (119–176)		0.24
BNP, pmol/mL, median (interquartile range)	199 (143–704)	186 (115–298)		0.57
D-dimer, μg/mL median (interquartile range)	3.19 (0–10.5)	2.68 (1.61–5.4)		0.91
NIHSS, point, median (interquartile range)	20 (17–26)	22 (18–26)		0.19
ASPECTS, point, median (interquartile range)	7 (6–9)	5 (4–9)		0.28
O2DT, min, median (interquartile range)	109 (47.5–192.3)	216 (35.4–430.5)		<0.05
D2PT, min, median (interquartile range)	77.5 (41.3–114.3)	98 (70–115)		0.23
MRA and angiographical findings				
MRA, no. (%)				
Ipsilateral A1	15 (93.8)	24 (50.0)	15 (1.83–122.7)	<0.05
Ipsilateral M1	6 (37.5)	16 (34.4)	1.2 (0.36–3.89)	0.76
Patent MCA	6 (37.5)	15 (31.2)	1.32 (0.40–4.30)	0.64
Angiogram, no. (%)				
Posterior communicating artery	3 (18.8)	14 (29.1)	0.56 (0.14–2.28)	0.67
Ophthalmic artery	1 (6.3)	14 (29.2)	0.16 (0.02–1.35)	0.06
Probable occluded site, no. (%)				
CCA	2 (12.5)	1 (2.08)	6.71(0.57–797.7)	0.08
Cervical-petrous, no. (%)	7 (43.8)	21 (43.8)	1 (0.32–3.13)	0.89
Lacerum-C3, no. (%)	1 (6.3)	5 (10.4)	0.57 (0.06–5.31)	0.93
C2-C1, no. (%)	6 (37.5)	21 (43.8)	0.77 (0.24–2.46)	0.9
Tortuosity in cervical ICA, no. (%)	3 (18.8)	19 (39.6)	0.35 (0.09–1.40)	0.13
Stenosis in cervical ICA, no. (%)	1 (6.25)	3 (6.25)	1 (0.10–10.4)	1

ASPECTS: alberta stroke program early CT score; BNP: brain natriuretic peptide; CCA: common carotid artery; CI: confidence interval; D2PT: door to puncture time; ICA: internal carotid artery; NIHSS: National Institute of Health Stroke Scale; N-SS-BGC: no recanalization-manual suction with syringe via the balloon guiding catheter; O2DT: onset to door time; R-SS-BGC: recanalization-manual suction with syringe via the balloon guiding catheter

at present.[2] While the therapeutic results have also markedly improved in patients with embolic occlusion of the ICA,[4] challenges, such as improvement in the complete recanalization rate, shortening of P2RT, and reduction of complications including intraoperative ENT and EDT, still remain to be addressed. As one attempt to achieve these goals, concomitant proximal occlusion using a BGC during thrombectomy using a clot-retrieval device has been reported,[5] and this technique is presently a standard procedure for thrombectomy in Japan. In Japan, however, the introduction of clot-retrieval devices was delayed, and the usefulness of SS-BGC using a BGC during inflation of the coaxial balloon in the cervical ICA on the affected side has been reported in patients with embolic occlusion of the carotid artery.[6] Although SS-BGC is a very simple procedure, if it is successful, clots can be retrieved in a short period. At our institution, SS-BGC has been performed in all patients with embolic occlusion of the carotid artery before the use of a clot-retrieval device, but the usefulness of performing SS-BGC prior to thrombectomy using clot-retrieval device has not been established. In this study, the ICA could be recanalized by SS-BGC alone in 16 (25%) of the 64 patients. In such patients, complete recanalization was observed frequently, P2RT was shorter, no severe treatment-related complications were observed, and the outcome was often favorable. In this study, however, the significantly shorter O2DT in the R-SS-BGC group may have contributed to the high percentage of patients with a favorable outcome.

A disadvantage of SS-BGC is vascular damage during the approach to the cervical ICA with the BGC or inflation of the coaxial balloon in the ICA. In this study, vascular damage related to the BGC was confirmed in only one patient in the N-SS-BGC group. In this patient, marked vascular spasm was caused during retrieval of the clot-retrieval device as a BGC with an inflated coaxial balloon

Table 2 Procedure contents and outcomes

	R-SS-BGC group (n = 16)	N-SS-BGC group (n = 48)	Odds ratio (95% CI)	P value
Procedure contents				
Approach from brachial artery, no. (%)	2 (12.5)	3 (6.3)	2.14 (0.32–14.1)	0.41
Administration of t-PA, no. (%)	3 (18.8)	5 (10.4)	1.98 (0.41–9.44)	0.38
Multiple device, no. (%)	5 (31.2)	48 (100)	0.29 (0.08–0.97)	<0.05
Penumbra system, no. (%)	5 (31.2)	31 (64.6)		
Stent-retriever, no. (%)	1 (6.2)	18 (37.5)		
Merci retriever, no. (%)	0 (0)	7 (20.1)		
Aspiration catheter except penumbra system, no. (%)	0 (0)	8 (16.7)		
Urokinase, no. (%)	0 (0)	2 (4.2)		
Percutaneous transluminal angioplasty, no. (%)	0 (0)	4 (8.3)		
Backflow, no. (%)	2 (12.5)	15 (31.3)	0.31 (0.06–1.56)	0.14
Retrieved clots, no. (%)	16 (100)	10 (20.3)	-	<0.001
SS-BGC time - sec, median (interquartile range)	127 (24–275)	180 (30–300)		0.36
Outcomes				
TICI 2b-3, no. (%)	15 (93.8)	34 (70.8)	6.18 (0.74–51.3)	0.06
P2RT, min, median (interquartile range)	39 (18.5–81.3)	86.5 (47.8–117.3)		<0.001
O2RT, min, median	242.5 (181.3–319.3)	377 (260.5–647.3)		<0.05
TICI 2b-3 , no. (%)	15 (93.8)	34 (70.8)	6.18 (0.74–51.3)	0.06
Severe procedure-related complications, no. (%)	2 (12.5)	4 (8.3)	1.57 (0.26–9.52)	0.24
Extravasation, no. (%)	0 (0)	1 (2.0)		
Subarachnoid hemorrhage, no. (%)	0 (0)	0 (0)		
Intracranial hemorrhage, no. (%)	1 (6.2)	1 (2.0)		
ENT/EDT, no. (%)	1 (6.2)	1 (2.0)		
Vessel injury in ICA, no. (%)	0 (0)	1 (2.0)		
Symptomatic ICH, no. (%)	1 (6.3)	0 (0)		0.08
3 month mRS: 0-2, no. (%)	10 (62.5)	11 (22.9)	5.6 (1.66–18.9)	<0.05
Death within 3 month, no. (%)	2 (13.3)	8 (17.0)	0.75 (0.14–3.99)	0.73

Back flow: appearance of backflow immediately after dilation of the coaxial balloon of balloon guiding catheter; ENT/EDT: embolization to new territory/embolization to distal territory; mRS: modified rankin scale; O2RT: onset to recanalization time; P2RT: puncture to recanalization time; SS-BGC: syringe suction via BGC

was unintentionally elevated to the distal portion of the cervical ICA. Fortunately, severe complications could be avoided in this patient. Another disadvantage of SS-BGC is the risk of induction of ENT or EDT by SS-BGC before the use of the clot-retrieval device.[7] If the ipsilateral PcomA or OphA alone is made patent after only the proximal part of the clot has been retrieved by SS-BGC, the anterograde blood flow of the ICA flowing into the ICA via these arteries may cause clot migration despite proximal flow control with BGC, resulting in ENT or EDT. At our institution, we do not deflate the coaxial balloon of the BGC placed at the origin of the cervical ICA on the affected side, in principle, until backflow appears from the hub side after inflation of the balloon. However, as mentioned above, backflow also appears if the PcomA or OphA is made patent while the ICA remains occluded. In this situation, anterograde angiography after deflation of the coaxial balloon becomes necessary, and the risk of the occurrence of ENT or EDT increases. In this study, the ipsilateral PcomA or OphA was recanalized earlier during SS-BGC in no patients in the R-SS-BGC group and only three patients in the N-SS-BGC group. Fortunately, however, none of these three patients developed ENT or EDT. Eventually, ENT or EDT occurred in one patient in each group, but both cases were related to the use of the clot-retrieval device. As in these cases, there is always the risk of the occurrence of ENT or EDT during the passage of the device through the clots, techniques, such as the concomitant use of the stent-retriever and Penumbra system, are proposed to reduce such complications.[8]

Compared with the time before the advent of clot-retrieval devices, when recanalization of the ICA was attempted by SS-BGC alone,[6,9] the ICA recanalization rate by SS-BGC alone has been expected to improve due to the improvement in the guidability and the increase in the luminal diameter of the BGC. However, in the present study, the ICA recanalization rate was only 25% in those who underwent SS-BGC, showing no increase compared with a previous report.[6] This may be explained by factors related to the properties of clots. The diameter of clots that

Table 3 Overall of PSESS-BGC in two groups and the details of the score in each case of R- SS-BGC group

PSESS-BGC	R-SS-BGC group (N = 16)	N-SS-BGC group (N = 48)
3, no. (%)	4 (25)	5 (10.4)
2, no. (%)	8 (50)	11 (22.9)
1, no. (%)	2 (12.5)	5 (10.4)
0, no. (%)	1 (6.3)	12 (25)
–1, no. (%)	1 (6.3)	7 (14.6)
–2, no. (%)	0	3 (6.2)
–3, no. (%)	0	5 (10.4)

	Patent A1	Patent M1:	Patent Pcom	Patent OphA	Tortuosity of cervical ICA	PSESS-BGC
Point	2	1	–1	–1	–1	
Case 1	Yes	Yes	No	No	No	3
Case 2	Yes	Yes	No	No	No	3
Case 3	Yes	Yes	No	No	No	3
Case 4	Yes	Yes	No	No	No	3
Case 5	Yes	No	No	No	No	2
Case 6	Yes	No	No	No	No	2
Case 7	Yes	No	No	No	No	2
Case 8	Yes	No	No	No	No	2
Case 9	Yes	Yes	Yes	No	No	2
Case 10	Yes	No	No	No	No	2
Case 11	Yes	Yes	No	No	Yes	2
Case 12	Yes	No	No	No	No	2
Case 13	Yes	No	Yes	No	No	1
Case 14	Yes	No	No	No	Yes	1
Case 15	Yes	No	Yes	Yes	No	0
Case 16	No	No	No	No	Yes	–1

PSESS-BGC means total number of points calculated by six predictive factors including patency of ipsilateral A1, patency of ipsilateral M1, patency of ipsilateral PcomA or/and OphA, and tortuosity of ipsilateral cervical ICA, in which two points, one point, and minus one point are given for patency of A1, patency of M1, and each patency of PcomA/OphA and tortuosity of the ICA, respectively. Upper table shows overall of PSESS-BGC in two groups. The cases with PSESS-BGC more than one point are seen in 87.5% of R-SS-BGC group. Below table shows the details of the score in each case of R-SS-BGC group. ICA: left internal carotid artery; N-SS-BGC: no recanalization-manual suction with syringe via the balloon guiding catheter; OphA: the ophthalmic artery; PcomA: posterior communicating artery; PSESS-BGC: predictive score for efficacy of syringe suction via the balloon guiding catheter

occlude the ICA is estimated from the luminal diameter of the ICA to be 3 mm at the end and ≥4 mm in the portion proximal to the cavernous segment, but the luminal diameter of the BGC is only about 2.3 mm (0.090 inches). Therefore, for clots to be removed from the body through the lumen of the BGC, they must be flexible enough to be deformed longitudinally to a diameter of less than 2.3 mm. This means that hard thrombi with a diameter of more than 2.3 mm cannot be retrieved by SS-BGC alone. Another reason that the ICA is difficult to be recanalized by SS-BGC alone is the spatial relationship between the occluded clot and patent arteries such as branches of the ICA, ACA, and MCA. The success of a thrombectomy with aspiration from the proximal end of the occluded portion, such as SS-BGC, is dependent on the spatial relationship between the clot occluding a vessel and patent vessels which are collateral flow or course of outflow. In the days when the Merci retriever was used, it was reported that well-developed leptomeningeal anastomoses and a lower systemic blood pressure increase the possibility for the retrograde blood flow to work on the clot occluding the vessel and improve the recanalization rate by thrombectomy.[10] This also applies to thrombectomy by SS-BGC for embolic occlusion of the carotid artery.

Regarding the characteristics of preprocedural vascular images in patients in whom the ICA could be recanalized by SS-BGC alone, Imai et al.[6] reported that thrombectomy was more often successful in patients with a thick ipsilateral A1. Based on the results at our institution, we have also reported that patent ipsilateral A1 and M1 can be promotive channels in SS-BGC and that patent ipsilateral PcomA and OphA can be inhibitory channels in SS-BGC in patients with embolic occlusion of the carotid artery.[11] Eesa et al.[7] reported that tortuosity of the carotid artery is an inhibitory factor in thrombectomy. In this study, also, more patients had patent ipsilateral A1 or M1, and fewer patients had patent ipsilateral PcomA or OphA or tortuous carotid artery, in the R-SS-BGC group (**Table 1**), not contradicting previous reports. In this study, however, the differences in delineation of the ipsilateral M1 and patent

MCA between the two groups were small (**Table 1**). One reason for the small differences is the clot properties. In patients with patent ipsilateral M1 including patent MCA type, an occluded site is often the proximal portion rather than the end of the ICA and the occluding clots have often hardness and largeness resulting in the maintenance of the patency from the end of the ICA to the MCA. If the vessel is occluded by such a hard and large clot, recanalization by SS-BGC alone is unlikely to be achieved because of the small luminal diameter of the BGC as observed above. On the other hand, if the area distal to the portion occluded by the clot is patent, this area corresponds to a promotive channel during SS-BGC which can produce retrograde blood flow to work on the clot. Thus, considering that some patients with occlusion of the proximal portion of the ICA have clots with hardness and a volume appropriate for retrieval via the BGC, we included patency of the ipsilateral M1 on preprocedural MRA as an item of PSESS-BGC.

In this study, additional analysis using PSESS-BGC was performed concerning the efficacy of SS-BGC. As a result, PSESS-BGC was suggested to be useful for the prediction of success or failure of ICA recanalization by SS-BGC alone. However, the R-SS-BGC group of our study included one patient with a PSESS-BGC of −1 (**Table 3**). Therefore, SS-BGC should be attempted at least once even in patients who show backflow on the hub side immediately after inflation of the coaxial balloon of the BGC due to the presence of inhibitory channels from before surgery. In addition, even if the ICA cannot be recanalized by SS-BGC alone, retrieval of clots results in a decrease in the clot volume in the carotid artery, which is advantageous in the subsequent thrombectomy using a clot-retrieval device.[7] Therefore, it is premature to consider that SS-BGC was ineffective in all patients of the N-SS-BGC group. Clots were partially retrieved by SS-BGC in 10 (20%) of the 48 patients in the N-SS-BGC group, and SS-BGC may have contributed to recanalization in such patients.

A limitation of this study is that it was a retrospective study conducted in a small number of patients at a single institution. In addition, verification of the usefulness of SS-BGC itself was impossible because the comparison between those who underwent and those who did not undergo SS-BGC was not made. Furthermore, as patients before the introduction of clot-retrieval devices were also included, the results may not accurately reflect the recanalization rate of the ICA by SS-BGC alone in the era of current thrombectomy devices. Therefore, evaluation by further accumulation of cases is necessary concerning the usefulness of SS-BGC, as well as a selection of patients in whom SS-BGC should be attempted first and appropriate timing of shift to thrombectomy using a clot-retrieval device.

Conclusion

Recanalization of the ICA could be achieved in 25% of the patients with acute embolic occlusion of the carotid artery by SS-BGC alone. As for characteristics of preprocedural vascular images in such patients, the ipsilateral A1 and M1 were more often patent on preprocedural MRA, and the ipsilateral PcomA and OphA were more often non-patent on angiography before recanalization. It is worth attempting SS-BGC first in patients with acute embolic occlusion of the carotid artery even today when thrombectomy using a clot-retrieval device has become the first choice.

Disclosure Statement

None of the authors has conflicts of interest to declare concerning this paper.

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