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Technical Note

Repeated-Manual Aspiration with Maximum Pressure (r-MAX): A New Technique of Mechanical Thrombectomy Using Syringe Aspiration

Yoshifumi Tsuboi,[1] Michihisa Narikiyo,[1] So Ohashi,[1] Takashi Kawagoe,[1] Ryo Nogami,[1] Keita Hashimoto,[1] Hidenori Matsuoka,[1] Hirokazu Nagasaki,[1] and Yuichi Murayama[2]

Objective: We report a new contact aspiration technique using syringe aspiration called repeated-manual aspiration with maximum pressure (r-MAX).

Case Presentation: From January 2020 to May 2021, 18 patients underwent mechanical thrombectomy with r-MAX for occlusion of the internal carotid artery, the first division of the middle cerebral artery (M1), and basilar artery occlusion. In this method, the aspiration catheter is first guided to the occlusion site, and then, two VacLok syringes are connected to the aspiration catheter. Next, the three-way stopcock is released in one direction. After 15 seconds, the direction of the three-way stopcock is switched. In the meantime, negative pressure is reapplied through the syringe, and the direction of the three-way stopcock is switched again. After reapplying negative pressure through the syringe and switching the three-way stopcock two more times, the aspiration catheter is removed. First-pass thrombolysis in cerebral infarction (TICI) scale 3 recanalization was achieved in 11 out of 18 patients (61.1%). In all, 11 patients (61.1%) achieved modified Rankin Scale scores of 0–2 at 90 days. Asymptomatic hemorrhage was observed in two patients (11.1%), and no patients had symptomatic hemorrhage.

Conclusion: The r-MAX technique using syringe aspiration can be employed as one of the methods of contact aspiration.

Keywords repeated-manual aspiration with maximum pressure, syringe aspiration, mechanical thrombectomy

Introduction

Mechanical thrombectomy has been reported to be effective in the treatment of acute ischemic stroke,[1,2] and is widely used in clinical practice. There are reports of various techniques being used for mechanical thrombectomy, such as a direct-aspiration first-pass technique (ADAPT),[3] manual aspiration thrombectomy (MAT),[4] continuous aspiration prior to intracranial vascular embolectomy (CAPTIVE),[5] and stent retriever- assisted vacuum-locked extraction (SAVE);[6] however, there is no consensus regarding which technique should be used during the initial attempt at mechanical thrombectomy.

It has been reported that the suction pressure exerted by syringes is high.[7,8] In addition, there are reports about the effectiveness of MAT using syringe aspiration.[4,9] With the advent of aspiration catheters compatible with syringe aspiration, this method might be further widely practiced in the future. However, since the volume that can be aspirated using a syringe is limited, there is a concern that applying high suction pressure continuously may be difficult. Therefore, we have devised a new contact aspiration technique in which maximum suction pressure can be applied repeatedly. We present here the method of applying this new technique called repeated-manual aspiration with maximum pressure (r-MAX), as well as report the outcomes of the patients for whom mechanical thrombectomy was performed using r-MAX.

[1]*Department of Neurosurgery, Kawasakisaiwai Hospital, Kawasaki, Kanagawa, Japan*
[2]*Department of Neurosurgery, Jikei University School of Medicine, Tokyo, Japan*

Received: November 29, 2021; Accepted: February 2, 2022
Corresponding author: Yoshifumi Tsuboi. Department of Neurosurgery, Kawasakisaiwai Hospital, 31-27, Omiyacho, Saiwai, Kawasaki, Kanagawa 212-0014, Japan
Email: tsuboyoshi@hotmail.com

Case Presentation

Patients of any age with occlusion of the internal carotid artery (ICA), the first division of the middle cerebral artery (M1), or the basilar artery (BA); having National Institutes of Health Stroke Scale (NIHSS) score ≥6; CT or diffusion-weighted imaging (DWI) Alberta Stroke Program Early CT Score (ASPECTS) ≥6; and absence of intracerebral hemorrhage (ICH) on CT were included. If the time of onset was unknown or more than 6 hours had passed since the onset, patients with a mismatch between the neurological symptoms and DWI findings or with an ischemic core volume of less than 50 mL on CT perfusion imaging were included. This ischemic core was measured using workstation (Vitrea version 8.7; Canon Medical Systems, Tochigi, Japan). Ischemic core volume of 50 mL or less was based on the criteria of the DAWN trial.[10] Patients with tandem occlusions or stenosis were not included in this study. Eighteen patients underwent mechanical thrombectomy with r-MAX between January 2020 and May 2021.

The procedure for r-MAX is as follows (**Fig. 1**). In the case of occlusion of the anterior circulation, 9-Fr balloon-guiding catheter (BGC) (9-Fr Optimo [Tokai Medical Products, Aichi, Japan] or 9-Fr Branchor [Asahi Intecc, Aichi, Japan]) is placed in the cervical segment of the ICA. In the case of occlusion of the posterior circulation, a 6-Fr. FUBUKI Dilator Kit (Asahi Intecc) is placed in the distal portion of the V2 segment. A microcatheter (Marksman [Medtronic, Irvine, CA, USA] or Phenom 27 [Medtronic]) is advanced to the proximal part of the occlusion site with the help of a 0.014-inch microguidewire (CHIKAI [Asahi Intec]). Subsequently, an aspiration catheter (SOFIA Flow Plus [0.070-inch inner diameter; MicroVention, Tustin, CA, USA] or React [0.068 or 0.071-inch inner diameter; Medtronic]) is navigated to the occlusion site. The microcatheter and micro guidewire should be kept as proximal to the clot as possible without allowing them to pass through it; however, if it is difficult to guide the aspiration catheter, they should be advanced distal to the clot before guiding

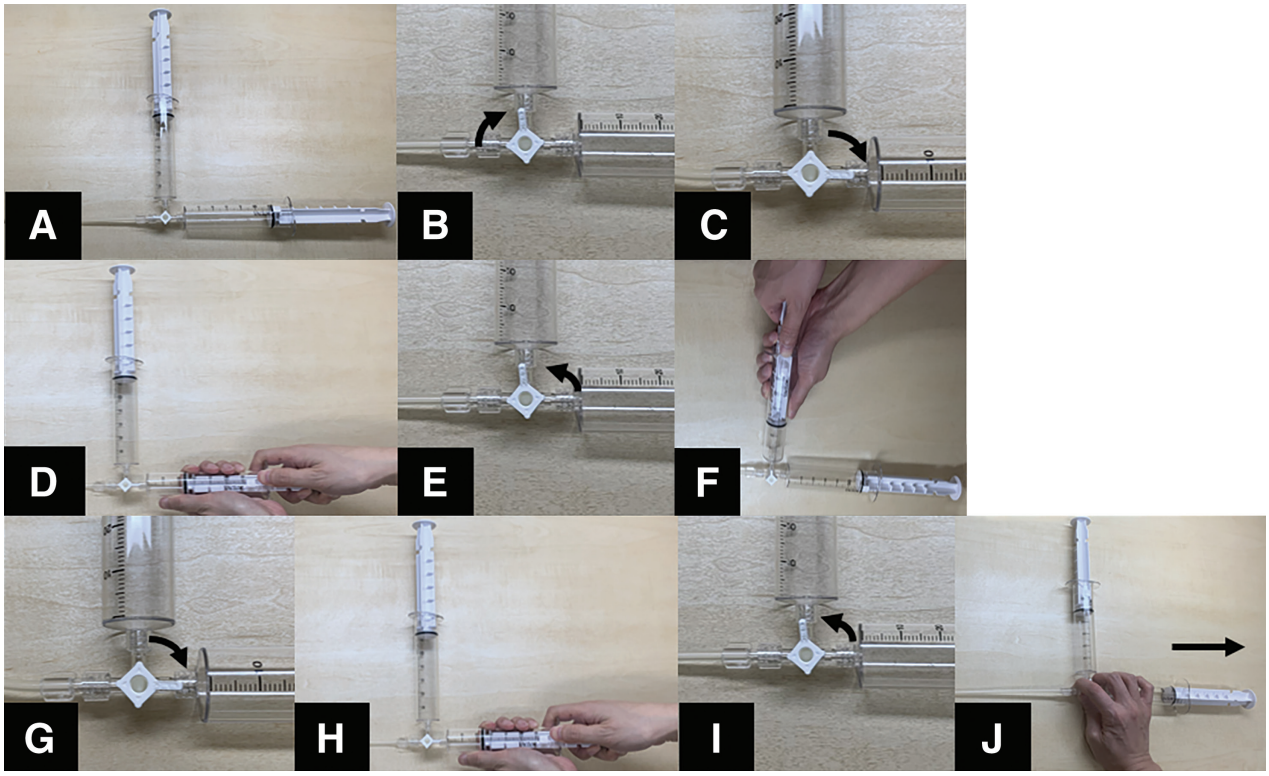

Fig. 1 The method of r-MAX. (**A**) After guiding the aspiration catheter to the occlusion site, two VacLok syringes are connected to the aspiration catheter. (**B**) The three-way stopcock is released in one direction (arrow). (**C**) After 15 seconds, the direction of the three-way stopcock is released in the other direction (arrow). (**D**) In the meantime, air and blood in the syringe are discarded, and the negative pressure through the syringe is reapplied. (**E**) The direction of the three-way stopcock is switched (arrow). (**F**) Similarly, after discarding the blood and air in the syringe, the negative pressure through the syringe is reapplied. (**G**) The direction of the three-way stopcock is switched (arrow). (**H**) The negative pressure through the syringe is applied again, and (**I**) the direction of the three-way stopcock is switched (arrow). The assistant switches the three-way stopcock and aspirates the syringe, while the operator holds the aspiration catheter. (**J**) Then, the aspiration catheter is removed (arrow). Clots are more likely to be missed at places where significant kinking of the blood vessel is present; therefore, the three-way stopcock is switched appropriately during the removal of the aspiration catheter. r-MAX: repeated-manual aspiration with maximum pressure

the aspiration catheter. Once the aspiration catheter has been guided to the proximal site of the clot, the microcatheter and microguidewire are removed. In case of the occlusion interrupting the anterior circulation, the proximal balloon is inflated. Two VacLok syringes (Terumo, Tokyo, Japan) are connected to the aspiration catheter. First, the 3-way stopcock is released in one direction. Suction is performed entirely under negative pressure, and if blood is aspirated, the aspiration catheter is advanced slightly and suction is reapplied. After 15 seconds, the direction of the three-way stopcock is switched. In the meantime, the syringe is removed, air and blood in the syringe are discarded, negative pressure is reapplied through the syringe, and the direction of the three-way stopcock is switched again. After reapplying the negative pressure through the syringe and switching the three-way stopcock two more times, the assistant switches the three-way stopcock and aspirates the syringe, while the operator holds the aspiration catheter. If blood is aspirated in the middle of the aspiration, the assistant checks to see if the clot has been drawn into the syringe. The aspiration catheter is then pulled back to the proximal side, and angiography is performed using the guiding catheter to confirm recanalization. If recanalization has not been achieved, mechanical thrombectomy is continued. After switching of the three-way stopcock four times, the aspiration catheter is removed. In a place with strong bending, clots are more likely to miss, so the three-way stopcock is switched during the removal of the aspiration catheter. If blood is aspirated during the removal of the aspiration catheter, it is considered that the clots have been pulled into the syringe or that they have been missed. Therefore, the aspiration catheter is removed and the syringe is checked for the presence of clots.

There were 11 male and seven female patients (**Table 1**). The median age of the patients was 76.1 years (range 45–95 years). The sites of occlusion were ICA in two cases (11.1%), M1 in 12 cases (66.7%), and BA in 4 cases (22.2%). The NIHSS score was 17.2 (range, 8–31) and CT or DWI ASPECTS was 8.8 (range, 6–11). Mechanical thrombectomy was successfully completed in all cases. In one case (case 6), a direct carotid artery puncture was performed because the transfemoral artery approach was not possible after aortic stenting. In one case (case 7), it was difficult to navigate the guiding catheter due to arterial tortuosity; hence, the aspiration catheter was guided directly from SEL-OSP (Medikit, Tokyo, Japan). First-pass TICI 3 recanalization was achieved in 11 out of 18 patients (61.1%), and first-pass TICI 2b or higher recanalization was achieved in 12 out of 18 patients (66.7%). A final recanalization result of TICI ≥2b was achieved in all cases. Of the six patients who did not achieve recanalization in the first pass, one patient underwent r-MAX again during the second pass and the remaining five patients achieved recanalization with a stent retriever following the second pass. Of the 13 cases in which recanalization was achieved solely with r-MAX, in four cases, we were able to collect the clots when switching the three-way stopcock before removal of the aspiration catheter; in six cases, there was backflow of blood during aspiration catheter removal and we were able to collect the clots in the syringe, and in three cases, we were able to collect the clots while they were trapped in the tip of the aspiration catheter. The mean time from puncture to recanalization was 34.9 minutes (range, 16–73 minutes). In all, 11 patients (61.1%) achieved modified Rankin Scale scores of 0–2 at 90 days. Distal embolization (DE) was observed in two patients (11.1%); however, there was no case of embolization of new territory (ENT). Asymptomatic hemorrhage was observed in two patients (11.1%), and there were no cases of symptomatic hemorrhage.

Representative case (Number 16) (Fig. 2)

Patient: A 65-year-old male. After complaining of dizziness, his level of consciousness deteriorated, and he was taken to our hospital 107 minutes after the onset of symptoms. The NIHSS score was 14 and CT ASPECTS was 10. Mechanical thrombectomy was performed for occlusion of the right middle cerebral artery occlusion. A 9-Fr long sheath was placed in the right femoral artery. A 9-Fr Optimo was guided up to the cervical segment of the right ICA using a 6-Fr JB2 (Medikit) as an inner catheter. Initial angiography showed proximal occlusion of the right middle cerebral artery. Marksman was advanced to the proximal part of the occlusion site using a 0.014-inch CHIKAI. Subsequently, SOFIA Flow Plus was navigated to the occlusion site. After the proximal balloon was inflated to block the blood flow in the ICA, VacLok syringes were connected to SOFIA Flow Plus. After switching the three-way stopcock four times, SOFIA Flow Plus was removed and aspiration of blood was observed during its removal. Complete recanalization was achieved in one pass, and a red clot was found in the syringe. The time from puncture to recanalization was 22 minutes.

Discussion

Mechanical thrombectomy using syringe aspiration is known as MAT and has been shown to be effective and safe.[4,8,9]

Table 1 Summary of procedural data

Patient number	Year	Sex	NIHSS	Site occlusion	Guiding catheter	Aspiration catheter	Number of passes	Final TICI score	Technique from the second pass	Stent retriever	DE	Asymptomatic bleeding	Puncture to reperfusion (minutes)	3-month mRS
1	79	M	23	BA	FUBUKI dilator kits 6 Fr 90 cm	React 68	1	3	–	–	–	–	54	3
2	78	M	11	Rt. M1	Optimo 9 Fr 90 cm	SOFIA Flow Plus	1	3	–	–	–	–	22	2
3	90	M	12	Lt. M1	Optimo 9 Fr 90 cm	SOFIA Flow Plus	1	3	–	–	–	–	19	2
4	73	M	23	Lt. M1	Optimo 9 Fr 90 cm	SOFIA Flow Plus	1	3	–	–	–	–	31	1
5	71	M	8	Lt. M1	Optimo 9 Fr 90 cm	SOFIA Flow Plus	1	3	–	–	–	–	31	1
6	67	M	26	Rt. M1	*Radifocus introducer 6 Fr 15 cm	React 68	1	3	–	–	–	–	50	6
7	95	F	10	Rt. M1	**SEL-OSP 8 Fr 83 cm	SOFIA Flow Plus	3	3	CAPTIVE	Solitaire Platinum 4 × 20 mm	+	–	44	2
8	45	F	24	BA	FUBUKI dilator kits 6 Fr 90 cm	SOFIA Flow Plus	3	2b	CAPTIVE	EmboTrap II 5 × 33 mm	–	+	16	3
9	88	F	16	Lt. M1	Branchor 9 Fr 90 cm	SOFIA Flow Plus	1	3	–	–	–	–	28	1
10	80	M	20	BA	FUBUKI dilator kits 6 Fr 90 cm	SOFIA Flow Plus	1	3	–	–	–	–	20	1
11	70	M	16	Lt. ICA	Branchor 9 Fr 90 cm	React 71	1	3	–	–	–	–	73	3
12	87	M	13	Lt. M1	Branchor 9 Fr 90 cm	React 68	2	3	r-MAX	–	–	–	36	3
13	81	F	31	Lt. M1	Branchor 9 Fr 90 cm	React 71	3	3	CAPTIVE	Trevo XP 3 × 20 mm	+	+	34	3
14	75	F	23	BA	Branchor 9 Fr 90 cm	React 71	2	2b	CAPTIVE	Solitaire Platinum 6 × 40 mm	–	–	54	3
15	78	M	17	Rt. M1	Branchor 9 Fr 90 cm	React 71	1	3	–	–	–	–	21	1
16	65	M	14	Rt. M1	Optimo 9 Fr 90 cm	SOFIA Flow Plus	1	3	–	–	–	–	22	1
17	54	F	8	Rt. ICA	Optimo 9 Fr 90 cm	SOFIA Flow Plus	4	3	CAPTIVE	EmboTrap II 5 × 33 mm	–	–	42	1
18	93	F	15	Rt. M1	Branchor 9 Fr 90 cm	React 71	1	2b	–	–	–	–	32	1

*Radifocus introducer 6 Fr 15 cm: a direct carotid artery puncture was performed. **SEL-OSP 8 Fr 83 cm: the aspiration catheter was guided directly from SEL-OSP. BA: basilar artery; CAPTIVE: continuous aspiration prior to intracranial vascular embolectomy; DE: distal embolization; F: female; Lt: left; M: male; mRS: modified Rankin Scale; NIHSS: National Institutes of Health Stroke Scale; r-MAX: repeated-manual aspiration with maximum pressure; Rt.: right; TICI: thrombolysis in cerebral infarction

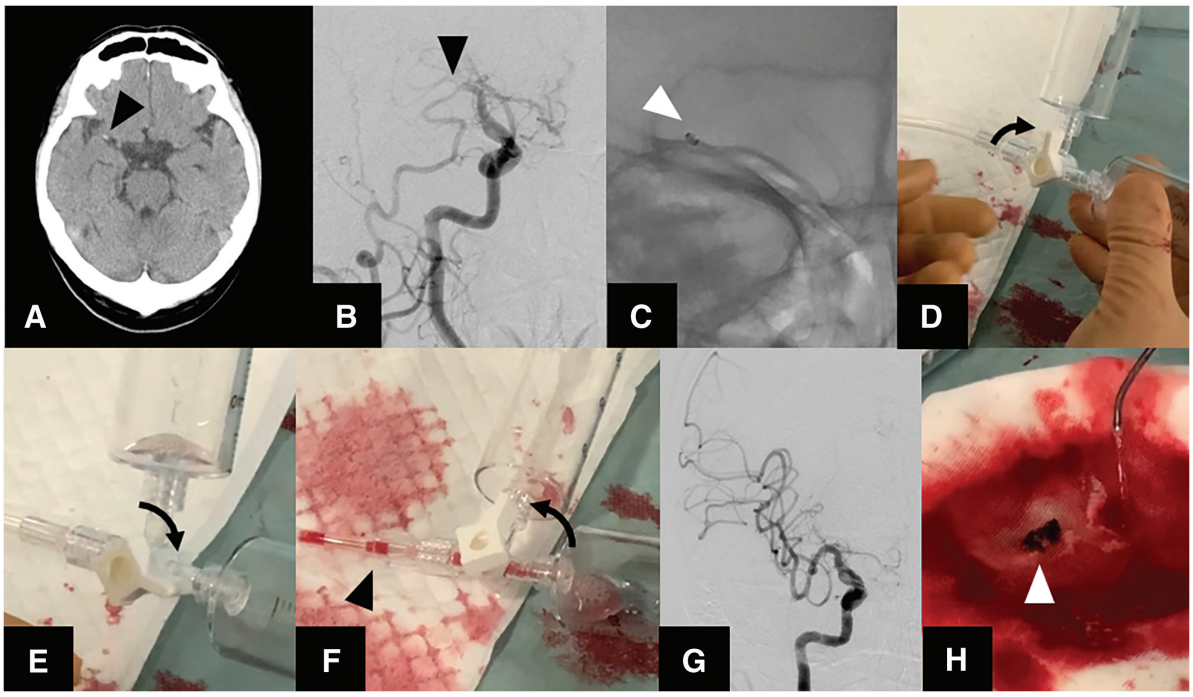

Fig. 2 (**A**) CT shows high-density area in the right middle cerebral artery (arrowhead). (**B**) Angiography shows proximal occlusion of the right middle cerebral artery (arrowhead). (**C**) SOFIA Flow Plus was navigated to a position to the occlusion site using CHIKAI and Marksman. Arrowhead: tip of the SOFIA Flow Plus. (**D**) The three-way stopcock was opened (arrow), and suction was initiated. (**E**) After 15 seconds, the direction of the three-way stopcock was switched (arrow). In the meantime, the negative pressure through the syringe was reapplied. (**F**) The direction of the three-way stopcock was switched (arrow). At this time, the blood and air in the tube were removed considerably (arrowhead). After repeating this procedure twice, SOFIA Flow Plus was removed. (**G**) Angiography showed complete recanalization (TICI 3). (**H**) A red clot was confirmed in the syringe (arrowhead). TICI: thrombolysis in cerebral infarction

However, due to the limited capacity of syringes, they can only aspirate a certain amount of blood, and there is concern that aspiration of air and blood will gradually reduce the aspiration force. r-MAX can overcome these drawbacks because the maximum suction pressure can be applied multiple times by switching the three-way stopcock even if the suction pressure decreases. In addition, r-MAX is a cost-effective technique. The cost of the VacLok syringe used in this method is 15000 yen, but this cost is considered less compared to the cost of using multiple devices or a pump.

Two experiments measuring the suction pressure of the syringes showed that suction pressure was higher than that exerted by the Penumbra pump (Penumbra, Alameda, CA, USA).[7,8] It has been conjectured that the reason for this is that the suction pump has a suction tube and a canister; hence, some pressure might be lost. Irrespective of using a suction pump or a syringe, the principle of suction is to create a vacuum in the aspiration catheter, and the suction can be performed due to the pressure difference with atmospheric pressure. In syringe aspiration, there is no tube or canister, and the vacuum power is directly transmitted to the aspiration catheter, which can efficiently create a vacuum condition; thus, the suction pressure is high.

In addition, variation in the suction pressure might also be useful in drawing the clot into the aspiration catheter. Arslanian et al. reported that cyclically varying the suction pressure between 18 and 29 inHg causes more clots to be drawn into the aspiration catheter compared to continuous suction.[11] Simon et al. compared continuous suction with varying suction pressure at 1, 2, and Max Hz (~6.3 Hz) and reported that the successful clearance rate of synthetic clots was better with varying suction pressure than with continuous suction and that Max Hz cleared clots faster than 1 and 2 Hz.[12] Gross et al. reported that when the syringe is filled with water, there is a slight decrease in suction pressure in the initial stage, and that the suction pressure drops sharply just before the syringe is filled,[8] suggesting that only a slight change in pressure may occur during r-MAX. However, when r-MAX is performed, the blood and air in the tube advance further considerably when the three-way stopcock is switched. It is considered that even a slight change in suction pressure may draw in the clot.

Hesse et al. reported that ADAPT has higher rates of ENT compared to combined treatment.[13] In this study, no case of ENT and DE was observed in two patients (11.1%).

The incidence of DE has been reported to be up to 14% and that of ENT to be 1%–11%;[14] thus, the incidence in r-MAX is not high. Although the number of cases in the study is small to conclude whether r-MAX can reduce the incidence of ENT and DE, r-MAX might reduce their incidence to lower than following ADAPT because it draws more clots into the catheter. Using r-MAX, we had more cases of retrieval before and during the removal of the aspiration catheter than cases where we were able to collect the clots while they were trapped in the tip of the aspiration catheter. This finding also suggests that r-MAX draws more clots into the syringe via the lumen of the aspiration catheter. It is also important to use a BGC to reduce the incidence of DE and ENT. There have been many reports on the effectiveness of BGC.[15,16] Zaidat et al. reported that BGC significantly improved the rate of first-pass effect and clinical outcome.[16] Lee et al. also reported that the incidence of DE could be reduced from 31.8% to 6.8% by using BGC.[15] It can be expected that the effectiveness and safety of the procedure will be further improved by using BGC for r-MAX.

Although two randomized controlled trials, the ASTER trial[17] and the COMPASS[18] trial, did not show that ADAPT was associated with fewer hemorrhagic complications compared with the stent retriever, Delgado Almandoz et al. reported that ADAPT was associated with significantly fewer hemorrhagic complications compared to those with the combined technique.[19] In this study, only two patients (11.1%) had an asymptomatic hemorrhage and none had a symptomatic hemorrhage. The two cases of asymptomatic hemorrhage involved the use of a stent retriever after the second pass, and no asymptomatic hemorrhage was detected in cases treated solely with r-MAX. r-MAX has the potential to minimize hemorrhagic complications because the vessel is less likely to be deflected during retrieval.

When using ADAPT during the first attempt, it was reported that rescue therapy was required in 20%–32.8% of the patients.[17,20] In this study, five out of 18 patients (27.7%) required the combined technique during the second pass. Although it may be difficult to successfully treat all patients with r-MAX alone, it has the advantages of being a simple, short, and cost-effective procedure that achieves thrombectomy without passing through the occlusion site.

The limitations of this study are that it is retrospective, the number of cases is small, and the selection of the occlusion site is biased. In addition, since some patients were treated with stent retriever during the second pass, the final recanalization rate cannot be attributed to r-MAX alone; only the recanalization rate of the first-pass can be considered. At present, it is difficult to confirm the effectiveness of r-MAX, and it can only be a verification of safety. In the future, it is necessary to prospectively verify the effectiveness of r-MAX in more patients.

Conclusion

The r-MAX technique using syringe aspiration can be employed as one of the methods of contact aspiration.

Disclosure Statement

The authors declare that they have no conflicts of interest.

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