# Aspiration Catheter Reach to Thrombus (ART) Sign in Combined Technique for Mechanical Thrombectomy: Impact for First-Pass Complete Reperfusion

Taichiro Mizokami, MD,* Takeshi Uwatoko, MD,† Kenichi Matsumoto, MD, PhD,* Yuichiro Ooya, MD,† Go Hashimoto, MD,† Motofumi Koguchi, MD,* Hideki Iwashita, MD,* Kiku Uwatoko, MD,‡ Hiroshi Takashima, MD, PhD,‡ Hiroshi Sugimori, MD, PhD,† and Syuji Sakata, MD, PhD*

*Objective*: The important factor for successful first-pass complete reperfusion (FPR) after combined techniques for mechanical thrombectomy (MT) is unclear. We consider that for successful FPR, the aspiration catheter (AC) should reach to and hold the thrombus before the device is pulled out. Therefore, we defined an ART (AC reached thrombus) sign characterized by the cessation of reverse blood flow in aspiration pump and deformation of stent retriever (SR) at the tip of AC. The purpose of this study was to identify the impact of the ART sign on the outcomes of the combined techniques. *Methods*: A retrospective analysis was conducted between January 2015 and September 2018 on the data of consecutive patients who underwent MT for anterior circulation stroke using both SR and AC at the first-pass procedure. We divided the patients into 2 groups based on whether the first-pass procedure achieved the ART sign (ARTs group) or not (Non-ARTs group). The primary endpoint was FPR defined as modified thrombolysis in cerebral infarction (mTICI) score of 3. *Results*: Sixty-six patients were included in our study (n = 38, ARTs group; n = 28, Non-ARTs group). There were no differences at mTICI 2b/3 (97.3% versus 89.2%, $P = .30$), but the FPR and mTICI3 were more common in the ARTs group (81.5% versus 14.2%, $P < .001$; and 89.4% versus 32.1%, $P < .001$, respectively). *Conclusions*: ART sign in combined technique was found to be an important factor for successful FPR.

**Key Words:** Thrombectomy—combined technique—first pass complete repercussion—aspiration catheter—stent retriever



## Introduction

Several types of combined technique for mechanical thrombectomy have been reported in the literature that has been supported by good outcomes.[1-8] However, the most important factor for successful first-pass complete reperfusion (FPR) after these combined techniques is not clear. We consider the position of aspiration catheter (AC) to be the most important factor responsible for FPR of the combined technique; the AC should reach the thrombus before the device is pulled out.

In this study, we have defined an ART (AC reached thrombus) sign characterized by the following observations: (1) reverse flow is stopped in aspiration pump (ART aspiration sign), and (2) shape of stent retriever (SR) at the tip of AC is

From the *Department of Neurosurgery, Saga-Ken Medical Centre Koseikan, Saga, Japan; †Department of Cerebrovascular Medicine, Saga-Ken Medical Centre Koseikan, Saga, Japan; and ‡Department of Neurology, Saga-Ken Medical Centre Koseikan, Saga, Japan.

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Address correspondence to Taichiro Mizokami, MD, Department of Neurosurgery, Saga-Ken Medical Centre Koseikan, 400 Nakabaru, Kase-machi, Saga City, Saga 840-8571, Japan. E-mail: mizmiztaich@gmail.com.

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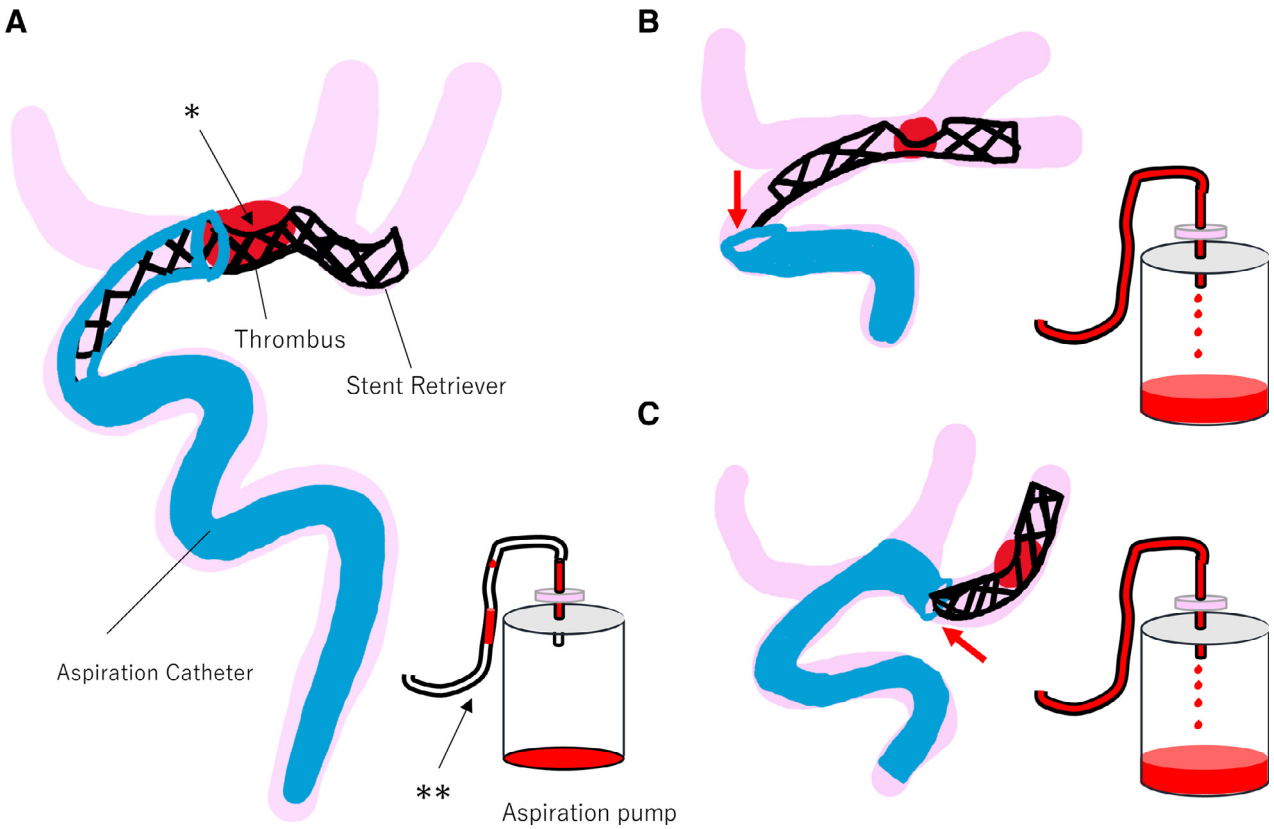


**Figure 1.** *Schematic illustration of ART sign. (A) The cessation of reverse blood flow in the aspiration tube (ART aspiration sign: **), and deformation of stent retriever just distal to the aspiration catheter (ART stent sign: *) revealed that aspiration catheter certainly reached the thrombus. On the other hand, ART aspiration sign and ART stent sign could not be achieved when the aspiration catheter could not reach the thrombus due to the ledge effect of the siphon (B) or steep curve of the MCA (C).*

changed (ART stent sign). The purpose of this study was to identify the effect of the ART sign on the procedural outcome of mechanical thrombectomy using combined techniques.

## Methods

A retrospective analysis of our institutional database was performed to identify consecutive patients who underwent mechanical thrombectomy at our institution between January 2015 and September 2018. The eligibility criterion for patient inclusion in our study was the presence of an occluded vessel affecting the anterior circulation (IC, M1, M2/3) where both SR and AC were used at the first-pass procedure. Patients with a tandem lesion, occlusion of the anterior cerebral artery, and posterior circulation stroke where either SR or AC was used alone at the first-pass procedure were excluded.

### *ART Sign*

ART sign is characterized by the following 2 observations: (1) cessation of reverse blood flow in the aspiration tube which connects AC and aspiration pump when the AC advances to thrombus (ART aspiration sign); and (2) deformation of the SR shape just distal from aspiration catheter tip (ART stent sign) (Fig 1A).

### *Non-ART Sign*

On the other hand, we observed that the AC could not reach the thrombus in one of the following situations: (1) in the presence of a ledge effect of the siphon or steep curve of the middle cerebral artery (MCA); (2) when the reverse blood flow could not be stopped in the aspiration tube (Fig 1B and C).

Operative records, including operative videos and angiography reports, were reviewed retrospectively to divide the patients into 2 groups based on whether the first-pass procedure achieved one of the ART signs (ART aspiration sign or ART stent sign) (ARTs group) or not (Non-ARTs group).

The patients in situations where the operator did not intend to advance the AC to thrombus and instead, used it as a Distal Access Catheter with SR fully withdrawn into the AC keeping the same position, were also added to the Non-ARTs group. Retrospective comparative analysis was then performed among these groups.

### *Combined Technique*

Under conscious sedation, a 9Fr balloon guiding catheter (BGC) (Optimo, Tokai medical, Aichi, Japan) was placed in the internal carotid artery (ICA). After initial intracranial angiography, the BGC was inflated and proximal flow was

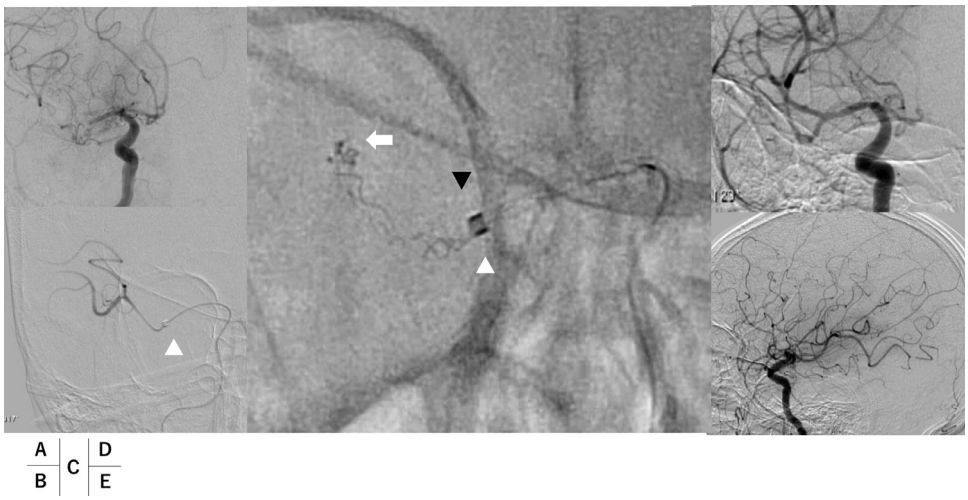


**Figure 2.** *Angiogram showing M1 occlusion. (A) Microcatheter was positioned distally from the thrombus, and the aspiration catheter was advanced to the thrombus with continuous aspirating by the connected pump till the reverse flow was stopped (ART aspiration sign). Angiogram through the microcatheter was performed, and the tip of the aspiration catheter (white arrowhead) reached the thrombus. (B) Stent retriever (Trevo Pro, white arrow) was deployed distally from the thrombus as possible to prevent the distal migration of the thrombus, and then we carefully confirmed the deformation of the stent retriever at the tip of aspiration catheter (ART stent sign: black arrowhead). (C) The unit was pulled out keeping the same position. Successful complete recanalization was achieved in 1 attempt (D, E).*

controlled to prevent distal migration of thrombus during the procedure, especially when microwire and microcatheter penetrated the thrombus. AC (ACE 60, ACE 68, 4MAX, Penumbra Inc, Alameda, CA), microcatheter (Marksman, Medtronic, Irvine, CA; Velocity, Penumbra Inc), and microwire were advanced to the intracranial. Irrespective of the occlusion site, the microcatheter was advanced as distally as possible from the MCA.

After this step, we followed different techniques for mechanical thrombectomy depending on the thrombus position. If the position of the thrombus was clear (MCA occlusion) (Fig 2A), we performed a modified combined technique for mechanical thrombectomy by swapping the steps of AC advancement and SR deployment. First, the AC that was connected to an aspiration pump and performed continuous aspiration was advanced to the thrombus to ensure reverse blood flow cessation in aspiration tube, which also indicated that the AC had reached thrombus (ART aspiration sign). Angiography was performed through this microcatheter to ensure that it was correctly positioned with respect to the thrombus (Fig 2B). SR (Trevo XP ProVue; Stryker, Kalamazoo, MI; Solitaire 2, Medtronic) of an appropriate size with respect to the occluded vessel was selected and deployed as distal as possible. Thereafter, we carefully checked for any deformation in the shape of the SR at the AC tip in a magnified X -Ray (ART stent sign) (Fig 2C). We removed the microcatheter after confirming ART signs. The AC was carefully pulled alone to avoid any deflection. After this, the AC and SR were slowly pulled out as a single unit without waiting for the SR to expand, where one of the operators kept SR and AC in the same position. Following this, manual aspiration was also performed with BGC.

If the position of the thrombus was not clear, especially in IC occlusion, we then performed the conventional combined technique for mechanical thrombectomy described as CAPTIVE, SAVE, PROTECT plus.[3,6,7] SR was deployed from distal M1 before the AC advanced to thrombus. The AC that was connected with an aspiration pump and performed continuous aspiration was advanced by the stent anchor technique till reverse blood flow was stopped (ART aspiration sign). This was followed by careful observation of SR shape at the tip of AC (ART stent sign). Hence, position of the thrombus was predicted by constriction of SR and stopped the reverse blood flow in the aspiration tube.

### *Clinical Endpoints*

The primary endpoint was FPR defined as modified thrombolysis in cerebral infarction (mTICI) score of 3.[9,10] The secondary endpoints included a mTICI 3, mTICI 2b/3, puncture to reperfusion time, number of passes, postprocedural subarachnoid hemorrhage, parenchymal hematoma, and modified Rankin scale at the time of discharge and after 90 days of onset.

### *Preoperative Characteristics*

Preoperative patient characteristics such as age, occluded vessels, Alberta Stroke Program Early CT Score (ASPECTS), National Institutes of Health Stroke Scale score, modified Rankin scale score (mRS), intravenous t-PA, onset-to-puncture time, and the rate of flow in BGC were also analyzed.

### *Radiological Analysis*

Pretreatment computed tomography or magnetic resonance imaging images were evaluated using the ASPECTS. Computed tomography scan was performed immediately and in 24 hours after the procedure to evaluate the

**Table 1.** *Baseline characteristics*

| | ALL n = 66 | ARTs n = 38 | Non-ARTs n = 28 | *P* value |
|---|---|---|---|---|
| Age | 80.6 ± 9.9 | 80.8 ± 9.0 | 80.2 ± 11.2 | .82 |
| Male (%) | 25 (37.8) | 15 (39.4) | 10 (35.7) | .80 |
| Hypertension (%) | 51 (77.2) | 30 (78.9) | 21 (75.0) | .77 |
| Dyslipidemia (%) | 19 (28.7) | 12 (31.5) | 7 (25.0) | .59 |
| Diabetes mellitus (%) | 8 (12.1) | 6 (15.7) | 2 (7.1) | .45 |
| Atrial fibrillation (%) | 51 (72.2) | 30 (78.9) | 21 (75.0) | .77 |
| Prestroke mRS0-1 (%) | 39 (59.0) | 20 (52.6) | 19 (67.8) | .30 |
| ASPECTS | 7.5 ± 2.3 | 7.5 ± 2.4 | 7.5 ± 2.2 | .97 |
| NIHSS on admission | 17.7 ± 6.5 | 17.7 ± 6.2 | 17.7 ± 7.1 | .99 |
| IV t PA (%) | 36 (57.4) | 20 (52.6) | 16 (57.1) | .80 |
| Onset to puncture (min) | 273 ± 164.1 | 261 ± 161.1 | 287 ± 168.9 | .67 |
| Occluded vessels | | | | |
| ICA (%) | 32 (48.4) | 21 (55.2) | 11 (39.2) | .20 |
| MCA-M1 (%) | 21 (31.8) | 12 (31.5) | 9 (32.1) | 1 |
| MCA-M2/3 (%) | 13 (19.6) | 6 (15.7) | 7 (25) | .30 |
| BGC (%) | 64 (96.9) | 37 (97.3) | 27 (96.4) | 1 |

Abbreviations: ARTs, aspiration catheter reach to thrombus sign; ASPECTS, Alberta stroke program early CT score; BGC, balloon guiding catheter; ICA, internal carotid artery; IV, intravenous administration; MCA, middle cerebral artery; mRS, modified Rankin scale; NIHSS, National Institute Of Health Stroke Scale; tPA, tissue plasminogen activator.

hemorrhagic complications. Regardless of whether symptomatic or asymptomatic, parenchymal hematoma type 1 and 2, remote parenchymal hematoma type 1 and 2, and subarachnoid hemorrhage were included in hemorrhagic complications according to the Safe Implementation of Thrombolysis in Stroke-Monitoring Study (SITS-MOST) classification.[11] All postprocedural angiograms were reanalyzed independently by 2 neuro-interventionists.

### *Statistical Analysis*

Statistical analysis was performed using JMP 9.0.2 version (SAS Institute, Cary, NC). The 2 groups were compared using the *t* test or chi-square test depending on the type of variable analyzed. Statistical significance was defined as *P* value is less than .05.

This retrospective study was approved by the institutional ethics review board.

## Results

Out of 158 cases of mechanical thrombectomy between January 2015 to September 2018, 66 were included in our study; 38 patients showed the ART signs (ARTs group) while the rest 28 patients did not (Non-ARTs group). In the ARTs group, ARTs aspiration sign was confirmed in all 38 patients and ART stent sign was observed in 25 patients. Stent signs were not observed when using a non-visualized stent. Baseline characteristics are summarized in Table 1.

There were no significant differences between the 2 groups with respect to age, sex, hypertension, dyslipidemia, diabetes mellitus, atrial fibrillation, mRS 0-1 before onset, ASPECTS, National Institutes of Health Stroke Scale on admission, usage of t-PA, time from onset to groin puncture, the location of occlusion vessel, and use of BGC.

Procedural outcomes are summarized in Table 2.

There were no differences at mTICI 2b/3 (97.3% versus 89.2%, $P = .30$), but the FPR and mTICI3 were more common in the ARTs group (81.5% versus 14.2%, $P < .001$; and 89.4% versus 32.1%, $P < .001$, respectively). Puncture to reperfusion time was lower for the ARTs group than for the non-ARTs group (44 minutes versus 59.5 minutes, $P = .012$). Hemorrhagic complications showed no difference between the 2 groups.

We could not find any significant difference in clinical outcomes of the 2 groups, although there was a higher rate of mRS 0-2 patients at 90 days in the ART group (42.1% versus 21.4%, $P = .11$).

## Discussion

This is the first study, which focused on the position of the AC when the device is pulled out in a combined technique of mechanical thrombectomy. We found that ART sign not only includes the cessation of reverse blood flow in aspiration tube as described before but also the deformation of SR, which is positioned distally from the AC tip.[3,6,7,12]

Recently, by the development of mechanical thrombectomy, more favorable procedural outcomes are possible.[10,13-17] The goal for the procedural outcome of recent mechanical thrombectomy techniques was to get an mTICI 3 score at the first-pass procedure, which means the thrombus was captured as a single mass without breaking it down and thereby not causing any distal emboli.[3,6,7,12,17] mTICI 2b and 3 have been defined as successful recanalization, but mTICI 3 indicated a better

**Table 2.** *Procedual outcome*

| | ALL | ARTs | Non-ARTs | *P* value |
|---|---|---|---|---|
| | 66 | 38 | 28 | |
| Aspiration sign (%) | | 38 (100) | | |
| Stent sign (%) | | 25 (65.7) | | |
| Number of passes | 1.6 ± 1.3 | 1.4 ± 1.5 | 1.9 ± 1.0 | .069 |
| Puncture to recanalization (min) | 50.6 ± 25.4 | 44 ± 25.6 | 59.5 ± 22.5 | .012 |
| mTICI 2b/3 (%) | 62 (93.9) | 37 (97.3) | 25 (89.2) | .30 |
| mTICI 3 (%) | 43 (65.1) | 34 (89.4) | 9 (32.1) | <.001 |
| 1 pass mTICI 3: FPR (%) | 35 (53.0) | 31 (81.5) | 4 (14.2) | <.001 |
| Hemorrhagic complications (%) | 11 (16.6) | 6 (15.7) | 5 (17.8) | 1 |
| NIHSS at discharge (%) | 12.5 ± 12.6 | 11 ± 11.4 | 14 ± 14.0 | .25 |
| mRS 0-2 at discharge (%) | 15 (22.7) | 9 (23.6) | 6 (21.4) | 1 |
| mRS 0-3 at discharge (%) | 25 (37.8) | 16 (42.1) | 9 (32.1) | .40 |
| mRS 0-2 at 90 days (%) | 22 (33.3) | 16 (42.1) | 6 (21.4) | .11 |
| mRS 0-3 at 90 days (%) | 35 (53.0) | 20 (52.6) | 15 (53.5) | 1 |
| mRS 6 | 7 (10.6) | 3 (7.8) | 4 (14.2) | .40 |

Abbreviations: ARTs, aspiration catheter reach to thrombus sign; FPR, First pass complete reperfusion; mRS, modified Rankin scale; mTICI, modified thrombolysis in cerebral infarction; NIHSS, National Institute of Health Stroke Scale.

clinical outcome, lesser hemorrhage, and lesser mortality than mTICI 2b.[10,13-15,17] In addition, Zaidat O et al reported achieving mTICI 3 at first pass procedure was associated with a significantly higher rate of good clinical outcome. However, use of a simple stent with or without BGC only achieved 25.1% of FPR.[17] In our combined technique, if the ART signs were observed, then the rate of first-pass with an mTICI 3 was 81.5%, which is very high compared with that in previous studies.[1-3,5-8,12,17,18]

The significance of the ART sign was to hold the proximal end of the thrombus by outside of SR and AC, in addition to aspiration, and providing support to the distal end of the thrombus by the SR. This situation helped the thrombus to move out as a single mass without generating distal emboli. We consider that the most important advantage of SR was the ability to approach the distal end of the thrombus, but the disadvantage was its weak capturing power as the SR holds the thrombus outside of the stent and vessel wall, which results in slipping out of the thrombus, especially in a curved vessel.[18,19] On the other hand, the most important advantage of AC was its strong capturing power of the proximal end of thrombus by aspiration pump, while its disadvantage was that it tore off the thrombus leading to distal emboli.[18,20] To achieve the ART sign, the combined technique aimed to extract the advantages of SR and AC and to compensate for their disadvantages.

Recently, a novel combined technique was reported which arranges the use and order of proximal aspiration at AC and guiding catheter.[1-3,5-7,12] CAPTIVE uses continuous aspiration before opening the SR to provide distal emboli when the stent is opened.[7] SAVE was added to use proximal aspiration from guiding catheter, and PROTECT plus from the BGC.[3,6] These novel techniques were mainly discussed on to the timing and method of proximal aspiration from AC, guiding catheter and BGC. On the other hand, these technique also check cessation of reverse blood flow in aspiration tube when AC advances by stent anchor to thrombus.[3,6,7] These novel combined techniques should also mention the ART signs that we have suggested, but not describe the difficult cases to obtain the ART sign.[1,3,6,7] In our experience, some cases still existed for which it was difficult to obtain the ART sign owing to presence of strong vessel curve, friction of AC and SR, and distal position of thrombus. In order to smoothly advance the AC in such difficult cases, we modified the combined technique by swapping the AC advancement and SR deployment steps as described. We considered that the friction with SR could be avoided by advancing AC with a distally positioned microcatheter before SR deployment.

Limitations of our study include the following: a retrospective assessment of ART signs, use of mixed types of combined technique in the initial period of this study, self-reported angiographic data, and a small number of patients. The periods of study for the 2 groups were slightly different, and therefore, a learning effect could have existed. The clinical outcomes in our study were worse compared with those of previous studies; it could be because our study included patients with advanced age. We understand that ART sign is just a "sign" and not a technique and thus, the findings herein cannot be directly compared with those of previous studies.[1-3,5-7,12]

## Conclusions

ART sign in combined technique for mechanical thrombectomy was found to be an important factor associated with a successful FPR. For successful FPR in combined technique, the AC should reach to and hold the thrombus before the device is pulled out.

## Competing Interests

None declared.

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