Online October 6, 2023
Journal of Neuroendovascular Therapy 2023; 17: 257–262
DOI: 10.5797/jnet.ra.2023-0054

Review Article

Devices and Techniques

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This extensive review explores the intricacies of the three principal mechanical thrombectomy techniques: the stent retriever technique, contact aspiration technique, and a combined approach, and their application in managing acute ischemic stroke. Each technique operates uniquely on the thrombus, leading to differences in their efficacy. Factors including clot size, clot stiffness, vessel tortuosity, and the angle of interaction between the aspiration catheter and the clot significantly influence these differences. Clinical trials and meta-analyses have shown the overall equivalency of these techniques for the treatments of large vessel occlusion and distal medium vessel occlusions. However, there are nuanced differences that emerge under specific clinical circumstances, highlighting the absence of a one-size-fits-all strategy in acute ischemic stroke management. We emphasize the need for future investigations to elucidate these nuances further, aiming to refine procedural strategies and individualize patient care for optimal outcomes.

Keywords ▶ mechanical thrombectomy, stent retriever technique, contact aspiration technique, combined technique

Introduction

The successful management of acute ischemic stroke (AIS), a leading cause of disability and mortality worldwide, hinges on timely intervention and efficient stroke treatments. Mechanical thrombectomy (MT) has revolutionized the landscape of stroke management with its promising ability to reduce disability in patients with AIS due to intracranial artery occlusion. MT involves the use of endovascular devices to remove the obstructing clot directly from the occluded arteries, thereby restoring blood flow to the brain tissue. Since the introduction of the Merci retriever, the first endovascular device for AIS, many stent retrievers (SRs) and aspiration catheter have been introduced with various sizes and lengths as well as multiple techniques.

This review aims to delve into the MT techniques, focusing on three primary techniques: contact aspiration (CA) technique, SR technique, and the combined technique (**Fig. 1**). By discussing the strengths and weaknesses of each method (**Table 1**), this review offers a comprehensive understanding of these techniques and aids in decision-making for optimal patient management.

Thrombectomy Techniques

SR technique

The SR technique was the first to establish evidence for treating large vessel occlusion (LVO) in AIS.[1)] This technique involves the delivery of an SR to the occlusion site through a microcatheter. The SR is deployed by unsheathing the microcatheter, initially pushing the thrombus against the opposite vessel wall. The interaction between the stent strut and thrombus is generally superficial, meaning the thrombus does not integrate into the stent lumen unless it is soft. The thrombus is then retracted along the vessel wall as the SR is pulled back.

Several factors influence the efficacy of SRs, including the size, stiffness, and location of the clot.[2)] The larger the clot, the less likely it is to be retrieved. SRs can easily penetrate soft thrombi with their struts, often allowing the clot

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Received: August 1, 2023; Accepted: September 6, 2023
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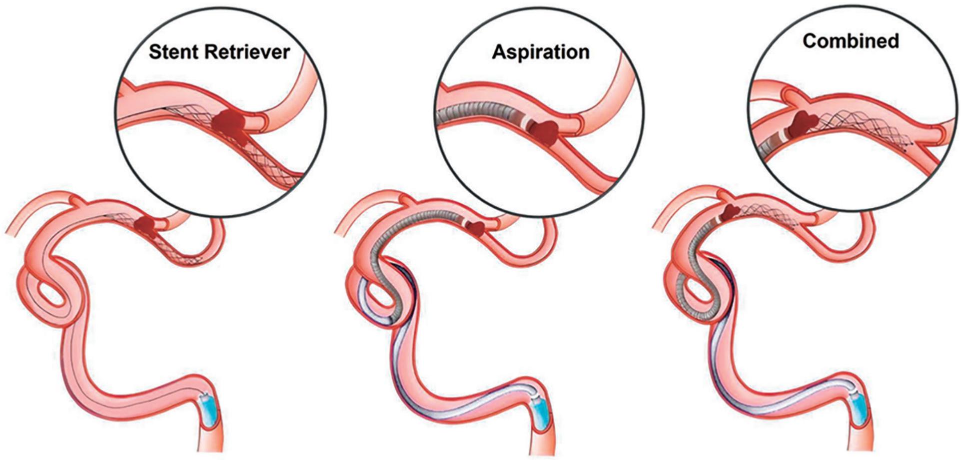

Fig. 1 Illustrations depicting various stroke treatment techniques. From left to right: SR technique, CA technique, and combined technique, showing a procedure that incorporates both the SR and CA methods. CA: contact aspiration; SR: stent retriever

Table 1 Strengths and weaknesses with each thrombectomy technique

	Strong	Weak
CA	Soft clot Small stiff clot Straight anatomy paths Effective with large bore	Long and stiff clot Clot in tortuous anatomy Less suction through a guiding catheter
SR	Clot with mild and moderate stiffness Effective with large and longer stent Large amount of suction from a guiding catheter	Stiff clot Clot in tortuous anatomy
Combined technique	Clot with a range of stiffness from soft to moderate Clot in tortuous anatomy	Less suction through a guiding catheter

CA: contact aspiration; SR: stent retriever

to enter the luminal side. Red blood cell-rich clots, in particular, tend to remain engaged with the devices during retrieval, leading to a higher rate of complete clot removal than with white fibrous thrombi.[3] However, very soft clots can be fragmented by the complete opening of the SR. Fibrin-rich pathology can reduce the efficacy of SRs.[4] Fibrin-rich clots are not easily penetrated by the stent struts but remain on the side of the devices, compressed against the vessel wall.[3] These clots do not expand but slide over the thrombus.

Vessel tortuosity can also reduce the efficacy of SRs.[5] In multiple tortuous curves, SRs tend to elongate and collapse while being pulled. This is more likely to occur when a long SR is used and put over the multiple curves. The stretching of the SR in tortuous bends leads to reduced interaction between the SR and the clot around the curve, resulting in a decrease in traction force against the clot or dislodgment of the clot.

In conclusion, the SR technique has emerged as a gold standard in AIS treatment, with its effectiveness supported by large clinical trials. However, its efficacy can be influenced by various factors, including the size and stiffness of the thrombus and the tortuosity of the vessel.

CA technique

The CA technique physically removes the obstructing clot from the vessel by sucking the clot or dragging the clot down by holding it at the tip of the aspiration catheter with the negative pressure.[6] The technique is simpler and quickest because the aspiration catheter only needs to be delivered proximal to the clot. Its efficacy is similarly dependent on various factors, including clot stiffness, vessel tortuosity as the SR technique, and also the angle of interaction (AOI) between the aspiration catheter and the clot.

The diameter of the occluded vessel and the diameter of the aspiration catheter used affect the successful recanalization rate. Recent studies suggest a strong correlation between higher catheter-to-vessel ratio (CVR; the ratio of the aspiration catheter internal diameter to the occluded artery diameter) and increased rates of successful recanalization.[7,8]

Stiffness of the clot also influence the efficacy of the CA technique. Our in vitro study showed aspiration catheters demonstrate efficacy in removing soft clots.[4] However, CAs can struggle with large, fragile clots in tortuous vessels. For example, clot fragmentation may occur during aspiration of large clots in the tortuous M1 segment, and difficulties can arise when dealing with stiff clots in tortuous M1–M2 segments. In addition, moderately stiff clots are not well integrated to the aspiration catheter tip, especially with low CVR. The CA technique is more dependent on the characteristics of the clot such as size and stiffness than is the SR, and it is difficult to predict what type of clot until the intervention is performed. Therefore, it would be safe not to perform CA if the thrombus appears long across the bending in the occluded artery on preprocedural imaging.

The angle between the aspiration catheter and the clot, referred as AOI, significantly impacts the success of CA.[9] Ideally, a favorable AOI greater than 125.5° (close to straight) has been shown to effectively remove clots of various sizes and consistencies. This angle, which is formed between the aspiration catheter and the clot within the vascular system, allows the catheter to fully engage with the thrombus, leading to optimal extraction. However, if the AOI is acute (less than 125.5°), CA may struggle to completely remove the clot, leading to a potential procedure failure. As such, assessing the AOI before or during the procedure is essential to ensure the catheter's optimal efficacy. In cases where CA appears ineffective due to unfavorable AOI, or long in tortuous artery, an alternative technique such as SR or the combined technique should be considered.

Combined technique

Recognizing the strengths and limitations of both SR and CA thrombectomy, a combined technique has been getting more popular to have synergistic effect with both the aspiration catheter and SR to maximize treatment efficacy.[10–16] This method usually involves initial clot engagement with an SR deployment and followed by an aspiration catheter navigation to the clot. Many variations of combined techniques have been reported and each reported combined technique varies in the following aspects.

The use of balloon guiding catheter, timing of balloon inflation and deflation, positioning of the aspiration catheter, timing of navigation of the aspiration catheter, microcatheter removal before suction, timing of aspiration from the aspiration catheter, timing of aspiration from the guiding catheter, pulling out the SR through the aspiration catheter (ingestion technique), or pulling out the aspiration catheter and SR together (pinching technique) may alter the movement of the thrombus, traction of distal vessels, potentially impacting the overall success and safety of the procedure.

The advantages of the ingestion technique include the ability to maintain continuous aspiration and the flexible transition to CA when necessary.[13] In addition, in cases where the vessels are tortuous, making catheter navigation challenging, a quick re-approach can be undertaken if the clot is not removed. Furthermore, the ingestion technique remains viable and safe even when a permanent stent is already placed in the proximal stenosis, ensuring that the stent does not get caught. However, a potential drawback to this method is the risk of shearing off the entrapped thrombus while pulling the SR into the aspiration catheter.

The pinching technique, on the other hand, offers the advantage of being able to grasp and extract hard clots that might not fully integrate with the SR.[17] A potential limitation could be that there's the necessity to navigate all devices, adding to the procedural steps if the thrombus is not successfully retrieved, thereby extending the procedural duration. Moreover, the relative positioning of the two devices can potentially change when initiating retraction, owing to the differences in the slack exhibited by each device. For example, the aspiration catheter may advance if the aspiration catheter is advanced to the clot by excessive pushing with the SR delivery wire pinning.

In conclusion, the combined techniques can potentially improve recanalization rates and lead to better clinical outcomes. However, these combined techniques may also increase procedure complexity and duration, which could be a drawback in some cases. It's important to note that the superiority of the combined technique compared to other techniques has not yet been definitively proven in positive clinical randomized trials.

Comparisons of the Three Techniques

The CA technique, SR technique, and their combination have been conducted in the context of LVO and distal medium vessel occlusion (DMVO). To date, no compelling evidence points to the superiority of one technique over the others.

The ASTER, ASTER 2, and COMPASS trials reported that all three techniques were equivalent in terms of efficacy and safety.[18–20] It is noteworthy, however, that certain subtleties emerged from the trials, hinting at potential variations in performance depending on the specific clinical context. For instance, the ASTER trial found that the revascularization rates were comparable between CA and SR techniques.[20]

Meanwhile, the ASTER 2 trial suggested that the combined use of CA and SR might offer a slight advantage in successful reperfusion rates after the first intervention compared to using the SR alone.[18] On the other hand, the COMPASS trial indicated that SRs as a first-line approach reached their revascularization target slightly more frequently than CA, albeit without a significant difference.[19]

When comparing the outcomes of MT anterior circulation LVOs and posterior circulation, it has been reported that anterior circulation LVOs have a higher incidence of atrial fibrillation, present with lower National Institutes of Health Stroke Scale scores, and manifest greater frequency in the administration of thrombolysis. Postprocedurally, these anterior circulation cases also exhibit a heightened incidence of symptomatic ICH, yet more favorable outcomes are observed compared to the posterior circulation cases.[21]

Specifically concerning anterior circulation LVOs, when comparing CA to SR, several studies have noted that the time to reperfusion is significantly reduced with CA. However, there appears to be no significant difference in terms of reperfusion rates and overall patient outcomes between the two techniques.[22–25] Observations in posterior circulation, primarily in vertebrobasilar artery occlusions, have similar tendencies. Notably, multiple reports indicate that CA yields a reperfusion success rate with an odds ratio of around 2.0 relative to SR, an increased first-pass effect, decreased incidents of embolization to new territory, and reduced necessity for rescue therapy.[26–29] As a result, considering CA as a first-line option appears reasonable.

Meta-analyses focusing on DMVO suggest that SR and combined techniques may yield higher success rates than CA when it comes to efficacy.[30] However, it's important to note that these methods come with a higher incidence of intraprocedural subarachnoid hemorrhage.

This reinforces the importance of balancing efficacy with potential risk in choosing the most appropriate method for MT. Each patient's unique clinical situation must be carefully considered to ensure the best possible outcome.

Thrombectomy and Thrombolysis

The combined application of thrombectomy and thrombolysis has been widely studied, with various trials including prospective randomized, nonrandomized, and retrospective studies. Meta-analyses have indicated that MT with intravenous thrombolysis results in a significant increase in successful reperfusion compared to standalone MT (odds ratio: 1.25, 95% confidence interval [CI]: 1.08–1.44). Furthermore, it has shown to enhance the likelihood of functional independence at 90 days (odds ratio: 1.42, 95% CI: 1.18–1.71) and reduce the mortality rate (odds ratio: 0.69, 95% CI: 0.60–0.80).[31] However, there are limited reports specifically assessing the influence of thrombolysis on each thrombectomy technique. Sub-analysis from randomized controlled trials (RCTs) suggests that in groups receiving thrombolysis, there is an observed increase in the first-pass effect for SRs. For CA, while there is no discernible difference in reperfusion rates, a noticeable increase in favorable outcomes has been reported.[32,33] Recently, the CHOICE trial demonstrated that adding intra-arterial lysis post-thrombectomy led to an 18% increase in favorable outcomes (modified Rankin scale 0–1) without elevating the risk of hemorrhage.[34]

As the intricate interplay between thrombolysis and thrombectomy continues to be elucidated, further research is anticipated to shed more light on their combined therapeutic potential.

Conclusions

This review of thrombectomy techniques in treating AIS indicates that SR, CA, and a combined approach present considerable efficacy in managing LVO and DMVO. Multiple clinical trials as well as meta-analyses show that no technique significantly outperforms the others in overall efficacy and safety. However, variances in performance are notable depending on the specific clinical context. Therefore, future research is needed to enhance the performance of these techniques and further understand the nuances of their application to optimize patient outcomes.

Disclosure Statement

Naoki Kaneko has been a consultant for Encompass, TG Medical, and NV Medtech. Satoshi Tateshima has been a consultant for Cerenovus, Stryker and Rapid Medical and also receives royalties from Python Vascular. The other authors have no personal or financial interest in any of the materials or devices described in this article.

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