*Review Article*

# Mechanical Thrombectomy: Emerging Technologies and Techniques

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*Background:* The treatment of acute ischemic stroke due to large vessel occlusion (LVO) has revolutionized in the last decade. We sought to compile the most relevant literature published about the evolution in treating this disabling and fatal disease. *Methods:* A literature review of recent studies describing early treatment options like intravenous tissue plasminogen activator to the latest mechanical thrombectomy (MT) techniques was performed. We described in a chronological order the evolution of LVO treatment. *Results:* Recanalization rates with newer techniques and MT devices approach a 90% of effectiveness. Timely interventions have also resulted in better clinical outcomes with approximately 50% of patient achieving functional independence at 90 days. At least 14 new third generation thrombectomy devices are currently being evaluated in in vitro and clinical studies. *Conclusions:* The treatment of LVO with MT is feasible and safe. MT is standard of care in treating acute ischemic stroke due to LVO.

**Key Words:** Thrombectomy—stent—acute ischemic stroke—stentriever

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## Introduction

According to the Global Burden of Disease Study of 2010, stroke is the second most common cause of death and the third most common cause of disability in the world.[1,2] Approximately 80% of strokes are ischemic and due to thromboembolic events. Historically, the first line of treatment of acute ischemic stroke (AIS) has been intravenous (IV) tissue plasminogen activator (tPA). The National Institute of Neurological Disorders and Stroke trial demonstrated in 1995 that IV tPA within 3 hours from symptom onset improved functional independence at 3 months, despite a slight increase in the incidence of symptomatic intracerebral hemorrhage (sICH).[3] Further trials evaluated the outcomes obtained with the intra-arterial (IA) administration of tPA, including the EMS, IMS II, and the RECANALISE trials. Likewise, alternative agents such as recombinant prourokinase (PROACT and PROACT II trials) and urokinase (MELT trial), showed some improvement in the clinical outcome of AIS patients, but recanalization rates with these combined IV/IA approaches were still low (Table 1).[4-9]

The low success of IV and IA thrombolysis to achieve recanalization of large vessel occlusions (LVO) prompted development of mechanical thrombectomy (MT). This was possible due to technological advances in endovascular surgery with better catheters to enable more distal access and better devices to safely change the angioarchitecture of brain vessels. The aim of the present review is to provide a chronological overview of the evolution of MT devices and techniques.

## Stentriever Thrombectomy Devices

In 2001, Ringer et al described 9 patient who underwent balloon angioplasty after inadequate recanalization with

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**Table 1.** *Major trials evaluating the intra-arterial administration of thrombolytics*

| Year | Study | Endovascular device | Recanalization success (% of patients) | Clinical outcome (% of patients) | sICH (% of patients) |
|---|---|---|---|---|---|
| 1998 | PROACT[7] | IA infusion of prourokinase | TIMI 2-3, 67% | 90-day mRS 0-1, 30.8% | 15.4% |
| 1999 | PROACT II[8] | IA infusion of prourokinase | TIMI 2-3, 66% | 90-day mRS 0-1, 26%<br>90-day mRS 0-2, 40% | 10% |
| 1999 | EMS[6] | IA infusion of tPA | TIMI 2-3, 55% | 90-day mRS 0-1, 33% | 11.8% |
| 2007 | IMS II[4] | IA infusion of tPA | TIMI 2-3, 60% | 90-day mRS 0-1, 33%;<br>90-day mRS 0-2, 46% | 9.9% |
| 2007 | MELT[9] | IA infusion of urokinase | Complete, 5.3%;<br>Partial ≥ 50%, 47.4% | 90-day mRS 0-2, 49.1% | 9% |
| 2009 | RECANALISE[5] | IA infusion of tPA | TIMI 2-3, 87% | 90-day mRS 0-2, 57% | 9% |

IA: Intra-arterial; sICH: symptomatic intracerebral hemorrhage; tPA: tissue plasminogen.

IA tPA.[10] Four patients had residual distal occlusion after angioplasty and 1 patient had hemorrhagic conversion. Fitzsimmons and Nelson reported one of the first cases of cerebral revascularization with deployment of a self-expandable stent (SES).[11] A Neuroform stent (Stryker) was deployed in an occluded left middle cerebral artery (MCA) after the IA infusion of a glycoprotein IIb/IIIa inhibitor. Multiple reports followed and angioplasty and stenting in AIS secondary to LVO became part of the endovascular armamentarium.[12] One of the main drawbacks of acute intravascular stenting to achieve recanalization was the need to use glycoprotein inhibitors, which increased the risks of hemorrhagic transformation, especially in patients whom received IV tPA.[13]

Mayer et al reported in 2002 their experience in the treatment of AIS with a self-expandable basket that had a stent configuration and was used to recanalize a basilar artery.[14] The device, named Neuronet (Guidant) was an earlier version of a retrievable stent. Unfortunately, the device was never commercially available.

Wakhloo et al tested the concept of clot/coil retrieval with an SES in both vitro and animal models.[15] An Enterprise stent (Codman) was partially deployed distal to the protruding coils. Subtle retraction of the stent caused the coil to become trapped within the stent struts, at which point the stent was resheathed. The system was then retracted, along with the coil, into the guide catheter positioned in the internal carotid artery.

Kelly et al reported in 2008 the successful recanalization of a right M1 occlusion with an Enterprise stent in a patient in whom IA thrombolysis was unsuccessful. The stent was deployed for 20 minutes and then reconstrained and removed. This report is the first account of a SES that was retrieved after achieving recanalization in AIS.[16]

The first reports of thrombectomy with a stentriever came from European centers. Castaño et al reported their experience in treating 20 patients with anterior circulation LVOs. Thrombolysis in cerebral infarction (TICI) 2b/3 was achieved in 90% of treated vessels and no procedural complications occurred. Two patients had symptomatic ICH and 9 patients achieved a modified Rankin score (mRS) ≤2 at 3 months.[17] The device used in this study was the Solitaire AB stent (Medtronic), which was initially designed and used in Europe for aneurysm remodeling with stent assisted coiling. The device was deployed for 1 or 2 minutes before retrieval. Recanalization required in average 1.4 passes. The successful off-label use of this stent prompted the creation of the Solitaire FR device with minimal modifications from the AB version, and specifically designed for treatment of AIS. The main difference with the new Solitaire was that it was not detachable. Solitaire FR became the first "stentriever."

## Merci Retriever and Penumbra System

In 2004, the Merci device was the first retrieval device cleared by the Food and Drug Administration (FDA) for MT.[18] It is composed of a nitinol coil-shaped memory wire which after deployment engages the clot. The device is then pulled back to extract the thrombus in a "corkscrew" fashion. The first study to demonstrate the effectiveness of MT for recanalization of LVOs was the MERCI trial.[19] Outcomes achieved with first-generation Merci systems (X5/X6) were assessed by the MERCI trial (n = 151). It demonstrated a 46% rate of recanalization defined as a thrombolysis in myocardial infarction (TIMI) grade 2-3. However, the functional outcome was suboptimal, with only 27.7% patients achieving a mRS score 0-2 at 90 days.[19] The second-generation Merci retriever (L5) was evaluated by the Multi-MERCI trial (n = 177). This study showed a better recanalization rate of 57.3%, and a better rate of favorable clinical outcomes (90 day mRS 0-2, 36%).[20]

The next device to be cleared by the FDA in 2008 was the Penumbra aspiration system. The original system applied continuous vacuum aspiration through a guide catheter and the thromboembolic material was fragmented with a "separator." Published safety and effectiveness reports with this device revealed progressive improvements in both recanalization and outcomes. The Penumbra Pivotal stroke trial demonstrated excellent revascularization rates, reaching TIMI 2-3 in 81.6% of