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Mechanical Embolectomy

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Mechanical embolectomy is the latest revolution in the management of acute ischemic stroke (AIS). In 1995, results from the National Institute of Neurological Disorders and Stroke (NINDS) rt-PA Stroke Study Group [1] demonstrated that within 3 hours of AIS onset, carefully selected patients derive significant clinical benefit at 3 months after intravenous administration of tissue plasminogen activator (tPA). Subsequent large placebo-controlled trials, including the European Cooperative Acute Stroke Study (ECASS) I, ECASS II, and ATLANTIS, have unsuccessfully attempted to expand this critical time window from 3 to 6 hours, because the benefit of therapy is outweighed by the risk of intracerebral hemorrhage (ICH) [2–5]. Pooled analysis of the intravenous tPA trials indicates that most of the benefit of intravenous tPA is derived when the drug is administered within 90 minutes of symptom onset, although a favorable outcome based on the 3-month modified Rankin score still persists if the drug is given within 4.5 hours from onset [6]. Stringent inclusion criteria and a restricted time window limit the use of intravenous tPA to only 2% to 6% of stroke patients, however, and only 10% of AIS patients arriving within the 3-hour window are treated with intravenous tPA [7,8].

Patients with large-vessel AIS derive less benefit from intravenous tPA than patients with lacunar or distal embolic strokes, because large-vessel occlusions have less than a 30% recanalization rate with intravenous tPA [9]. The phase IV Prospective Standard Treatment with Alteplase to Reverse Stroke (STARS) study [10] of intravenous tPA use confirmed the findings of others [11] that patients with indicators of large-vessel AIS, including an initial National Institutes of Health Stroke Scale (NIHSS) score greater than 10 and a hyperdense middle cerebral artery (MCA) sign on the baseline CT scan, have less favorable clinical outcomes with intravenous tPA.

Endovascular management of AIS is intended to enhance the degree of large-vessel recanalization and to improve clinical outcome. With cerebral artery occlusion, a central ischemic core undergoes rapid infarction if blood flow is not restored. Surrounding this core is a penumbra of hypoperfused tissue that remains potentially salvageable for several hours. The degree of viability depends on the intrinsic capacity of the tissue to resist ischemia and the extent and duration of regional hypoperfusion. As the time from stroke onset elapses, the amount of viable brain tissue diminishes and the risk of ICH increases. By limiting the amount of drug used, endovascular approaches also aim to lengthen the time window for AIS treatment by minimizing ICH.

Intra-arterial thrombolysis limits ICH through direct thrombolytic infusion by superselective catheterization. The Prolyse in Acute Cerebral Thromboembolism (PROACT) II study demonstrated

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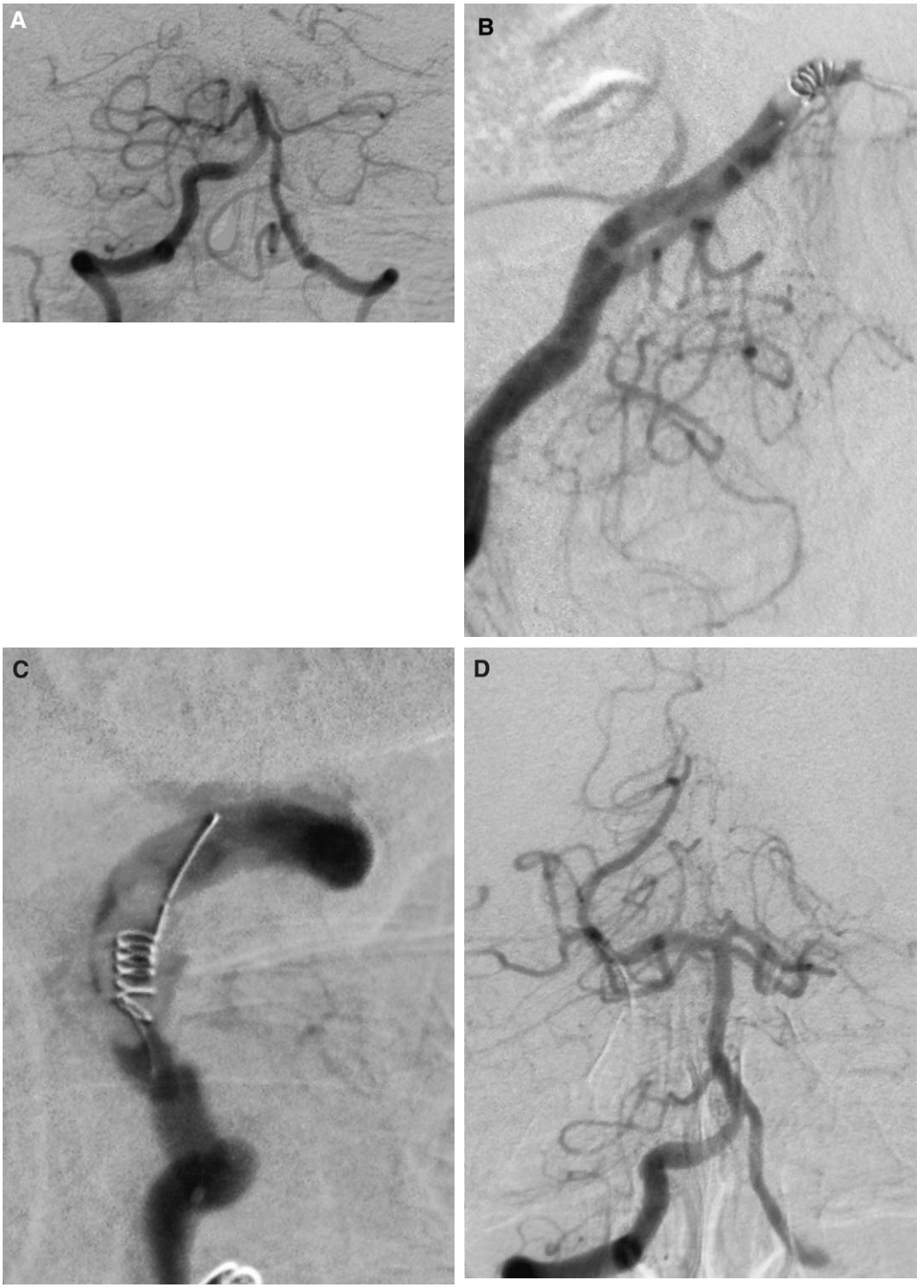
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successful MCA recanalization and greater functional independence in patients treated with intra-arterial prourokinase. Clinical benefit was achieved with a number needed to treat of seven at the expense of a 10% symptomatic ICH rate compared with 2% for control patients (and 6.4% in the NINDS intravenous tPA trial) with no mortality benefit [9]. After PROACT II, multiple intra-arterial thrombolysis series using tPA or urokinase have shown positive technical results and clinical outcomes. Based on personal experience and data showing a trend toward lower ICH complications with intra-arterial urokinase compared with intra-arterial tPA [12], we prefer to infuse urokinase intra-arterially. Recent data also indicate the efficacy and relative safety of intra-arterial glycoprotein (GP) IIb/IIIa inhibitors to treat intracerebral artery occlusion refractory to intra-arterial tPA, achieving complete or partial recanalization in 81% of 21 patients treated [13]. Our own experience with intra-arterial infusion of the GP IIb/IIIa inhibitor abciximab has been excellent. Although not approved for clinical use by regulatory agencies, intra-arterial thrombolysis is recommended for carefully chosen patients for the treatment of MCA and basilar artery occlusion by the American Heart Association and American Academy of Chest Physicians [14,15].

Mechanical embolectomy involves the use of novel endovascular devices to physically dissolve and remove thrombus and holds promise for advancing acute stroke management beyond the temporal and population limitations of chemical thrombolysis. Obviating the need for thrombolytic infusion to restore blood flow, mechanical embolectomy is potentially more rapid and aims to broaden the time window for AIS treatment and to expand therapy to patients with contraindications to thrombolysis. This includes patients with bleeding diatheses, recent trauma, surgery, gastrointestinal or genitourinary hemorrhage, noncompressible arterial puncture, ischemic stroke in the prior 6 weeks, past ICH, vascular malformation or brain tumor, and presumed pericarditis or septic embolus.

Mechanical embolectomy has historical precedent. Surgical embolectomy for cerebral artery occlusion was first reported by Welch in 1956 [16]. Multiple cases and small series were reported in subsequent decades that mostly involved embolectomy from the MCA [17–20]. After surgical dissection of the occluded artery, the embolus was located by a bulge and a bluish color of the arterial wall. The artery was occluded proximal and distal to the embolus by temporary clips. An arteriotomy was made through which suction and forceps were used to milk out the embolus. Extracted emboli were described as 1 to 3 cm long and were usually easy to remove with the exception of friable emboli originating from the aortic arch [17,18]. Surgical embolectomy fell out of favor because it was too invasive and required too significant neurosurgical expertise to perform it rapidly enough to support broader appeal.

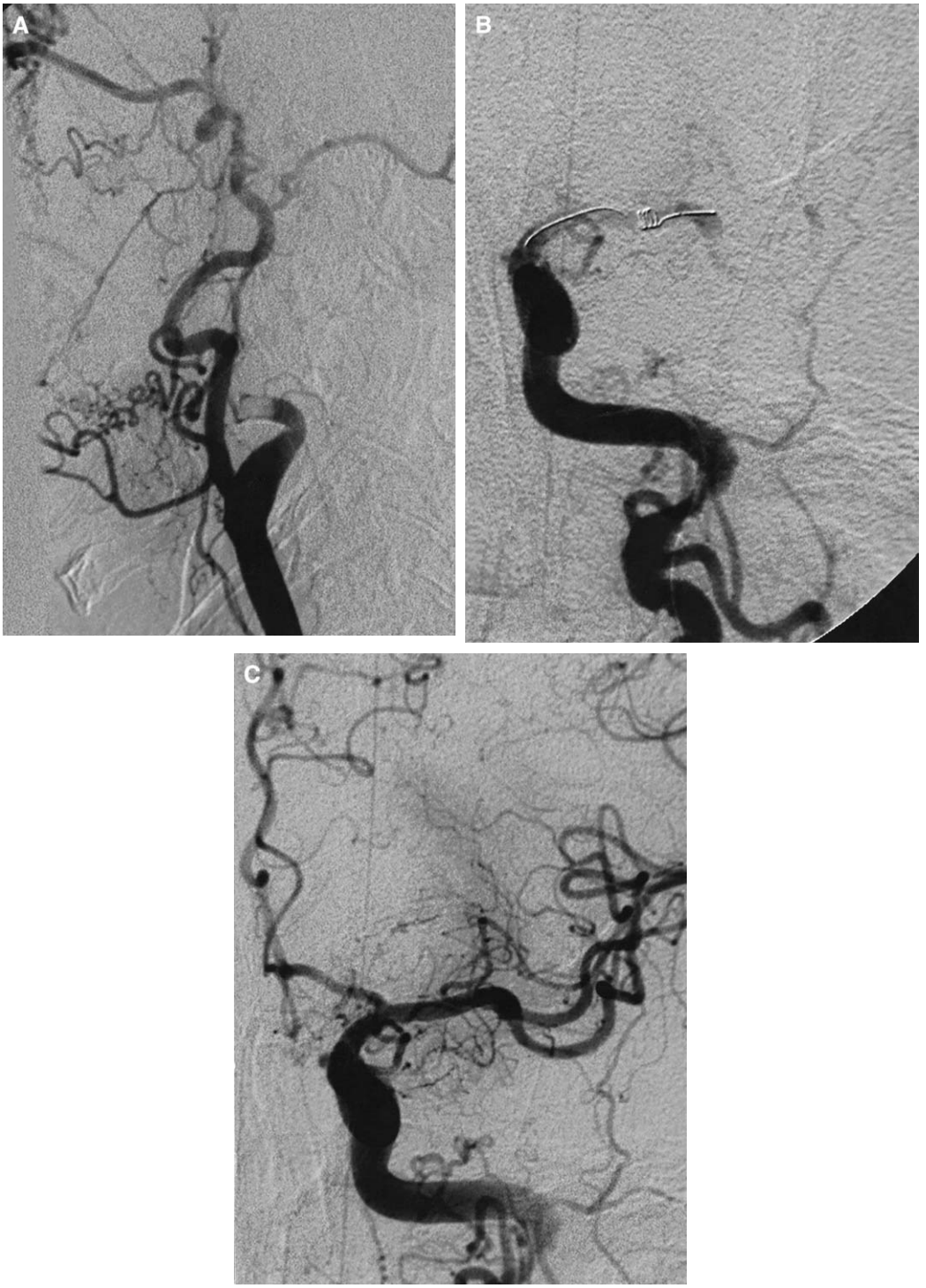
Devices and techniques

Thrombus retrieval devices

Merci Retriever

In August 2004, the Merci Retriever (Concentric Medical, Mountain View, California) was approved by the United States Food and Drug Administration (FDA) to recanalize cerebral vessels in AIS patients, making it the first clot retriever approved for this indication and the only other treatment that can be offered to AIS patients besides intravenous tPA. The Merci Retriever is a memory-shaped nitinol wire with five helical loops of decreasing diameter at the distal tip that maintains a straight configuration within a microcatheter. Using standard endovascular techniques, a microcatheter is advanced through the circulation to just distal to the occlusive thrombus. The guidewire is then withdrawn and exchanged for the Merci Retriever. As the retriever is directed through the distal end of the microcatheter, preshaped helical loops are released. The retriever is then retracted into the thrombus, ensnaring the clot (Figs. 1 and 2). Once

Fig. 1. (*A*) A 40-year-old woman presenting with vertigo, dysarthria, dysphagia, and left hemiplegia was found to have a midbasilar occlusion on digital subtraction angiography (anteroposterior view, vertebral injection). (*B*) The Merci Retriever was used to ensnare the clot 10 hours after symptom onset. (*C*) The thrombus shadow can be readily seen encircling the Merci device as the clot was retracted through the vertebral artery. (*D*) After mechanical embolectomy, the basilar artery lumen was restored. Several left posterior cerebral artery branches were still occluded; however, the territory was well perfused by left-sided collaterals and required no further treatment. The patient made a rapid and complete recovery.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the thrombus is secured, anterograde flow is impeded by inflation of a 9-French balloon guide catheter (BGC). The microcatheter, Merci Retriever, and thrombus are subsequently withdrawn through the BGC lumen and removed from the patient.

In the phase I [21] and II Mechanical Embolus Removal in Cerebral Ischemia (MERCI) Trials [22], 141 patients with a median baseline NIHSS score of 19 (range: 8–40) were treated using the Merci Retriever. Arterial recanalization was achieved in 48% of patients using the device alone, increasing to 57% when the retriever was used in conjunction with intra-arterial thrombolytics. The median procedure time was 1.8 hours. Treated occlusions included those of the MCA in 57%, internal carotid artery (ICA, including ICA "T" [ICA-T] occlusions) in 33%, and basilar artery in 9%. Successful recanalization resulted in functional independence in 47% of patients compared with 10% of those not revascularized and a significant difference in the 30-day NIHSS score (57% versus 15%, a $\geq$10-point improvement from the baseline NIHSS score).

Neuronet Endovascular Snare

The Neuronet Endovascular Snare (Guidant Corporation, Indianapolis, Indiana) is a nitinol basket attached eccentrically to a microguidewire with more distal than proximal struts that is threaded through a microcatheter past the thrombus [23]. Once the microcatheter is withdrawn, the memory-shaped basket captures the clot and the device is extracted under flow reversal. The device is being investigated in the Neuronet Evaluation in Embolic stroke Disease (NEED) trial in Europe. In a case series of five patients with acute basilar occlusion, two patients were successfully revascularized using the device alone and another patient was recanalized with combined mechanical and chemical thrombolysis [23].

Amplatz Goose Neck Snare

The Amplatz Goose Neck Snare (Microvena Corporation, White Bear Lake, Minnesota), unlike the Merci Retriever and the Neuronet Snare, was designed for endovascular foreign body removal, such as catheter fragments and dislodged aneurysm coils from the cerebral circulation, and not specifically for mechanical thrombolysis in acute stroke. The snare is advanced through a microcatheter and released just proximal to the thrombus, where it assumes a memory-shaped configuration perpendicular to the microcatheter and the vessel. The microcatheter-snare combination is advanced into the clot. The snare is then retracted slightly toward the microcatheter, and the system is pulled back a few centimeters. If the embolus is attached to the snare, as seen by selective angiography, the entire assembly, including the guide catheter, is extracted as a unit under hand suction. Snare size should be equivalent to the diameter of the thrombosed artery. Evidence for the efficacy of the Goose Neck Snare in acute stroke therapy comes from case reports and small series in which the device was used successfully to revascularize patients after failed chemical thrombolysis [24–26] or as a first treatment for large-vessel occlusions [27]. Personal experience with the Goose Neck Snare for the treatment of AIS has been disappointing, however. The snare's loop tends to pull through the arterial clot without adequately engaging the thrombus, making the device insufficient to treat most AIS patients.

Laser thrombolysis

Endovascular Photo Acoustic Recanalization laser system

The Endovascular Photo Acoustic Recanalization (EPAR) laser (Endovasix, San Francisco, California) achieves rapid thrombus dissolution by conversion of photonic energy to acoustic energy at the fiberoptic tip of the device through the generation of microcavitation bubbles [28]. Thrombus emulsification is not a consequence of direct laser-induced clot destruction. The catheter tip is designed with five lateral windows, each with one fiberoptic. Suction of the thrombus is induced by vaporization and reliquification of the cavitation pocket. Once in the catheter tip, the thrombus is emulsified and then ejected out of the catheter into the circulation as microparticles.

Fig. 2. (*A*) A 75-year-old woman presenting with global aphasia and right hemiplegia was found to have a left internal carotid artery (ICA) "T" occlusion with proximal ICA thrombus on digital subtraction angiography (lateral view, left carotid injection). (*B*) The Merci Retriever can be seen in the left MCA surrounded by thrombus (anteroposterior view, left carotid injection). (*C*) After embolectomy, intra-arterial urokinase and abciximab, and petrous carotid angioplasty and stent placement, the ICA, MCA, and anterior cerebral artery were fully recanalized and the patient made an excellent recovery (anteroposterior view, left carotid injection).

The 3-French EPAR microcatheter is guided past the thrombus, the power source is activated, and the laser is drawn back through the thrombus. Continuous infusion of the catheter with indigo carmine, an inert blue dye, is required as a coolant. In a phase I multinational trial [28], 34 patients with a median NIHSS score of 19 were treated. EPAR laser treatment could not be completed in 16 patients (47%) for primarily technical reasons. Sole complete use of the EPAR laser in 18 patients resulted in an immediate recanalization rate of 61% after a mean lasing time of 9.65 minutes. Thirty-day functional independence and a 50% or greater improvement in NIHSS score occurred in 36% of EPAR laser-revascularized patients.

LaTIS neuro laser thrombolysis system

The LaTIS laser device (LaTIS, Coon Rapids, Minnesota) uses photonic energy for thrombus ablation and can be deployed in arteries between 2 and 5 mm in diameter [29]. The optical fiber bundle in the delivery microcatheter uses a pulse dye laser-emitting 577-nm light that is discriminantly absorbed by thrombus and not the vessel wall [30]. An initial safety and feasibility report indicated that the device could not be delivered to the clot in two of the first five treated patients, prompting a revision in catheter design. Rapid clot ablation in one patient after three laser rounds in 49 seconds illustrates the potential utility of this technology; however, a decision has been made not to pursue an efficacy trial of this device [29,30].

Thrombus obliteration devices

Angiojet rheolytic thrombectomy system

The utility of rheolytic thrombolysis has been demonstrated for the recanalization of dural venous sinus thromboses [31–33]. The size and stiffness of the original Angiojet catheter (Possis Medical, Minneapolis, Minnesota) made it inappropriate for intracranial arterial use, although case reports of successful revascularization of basilar and proximal ICA thromboses have been reported [34,35]. The Angiojet uses high-pressure saline jets directed back into the catheter, creating a vacuum that fragments and aspirates the surrounding clot as the device is passed through the thrombus. Although a smaller device was designed to engage the clot in the intracerebral circulation, the phase I Thrombectomy in Middle Cerebral Artery Embolism (TIME) trial has been aborted by the company [29].

X-sizer Catheter System

The X-sizer Catheter System (EndiCor Medical, San Clemente, California) is a dual-lumen catheter containing a helical cutter in its inner lumen that is connected to an external vacuum device. When the system is activated, the helical blades rotating at 2100 rpm fragment the targeted thrombus, which is then suctioned out of the patient through the catheter's outer lumen [36]. The vacuum acts to pull the clot into the catheter tip, thereby averting damage to the vessel wall. The device is currently used during percutaneous coronary interventions and is being modified for thrombectomy in the cerebral circulation.

Percutaneous balloon angioplasty and stenting

Acute angioplasty and stenting is the standard of care for the treatment of acute coronary syndrome (ACS), achieving significantly more rapid vessel recanalization rates and improved clinical outcomes compared with chemical thrombolysis. Angioplasty for the management of AIS has been disappointing, however, mainly because the pathophysiology of AIS and ACS is different. Most ACS result from acute atherosclerotic plaque rupture with subsequent arterial thrombosis. Angioplasty of calcified atherosclerotic plaque results in cracking and dissection of the atherosclerotic lesion, restoring luminal patency that is stabilized by the placement of a stent. In contrast, many AIS arise by embolic occlusion of nondiseased vessels. Angioplasty of fresh embolus tends to displace the clot laterally. When the balloon is deflated, the thrombus rebounds back into an occlusive position. Acute angioplasty and stenting is most successful when treating AIS resulting from hypoperfusion from a stenotic extracranial or intracranial lesion or intracerebral arterial thrombosis from atherosclerotic plaque rupture or when a proximal stenosis precludes advancement of a microcatheter to a distal embolic lesion for intra-arterial chemical or mechanical thrombolysis. Balloon angioplasty is performed by advancing a balloon catheter into the occlusion site, followed by balloon inflation up to 6 atm for 30 seconds. A repeat angiogram is then obtained to evaluate the degree of recanalization. If stenosis and/or occlusion persists, the balloon is inflated successively until complete recanalization is achieved. We prefer to place a balloon-expandable stent after the initial balloon inflation, and then angioplasty the stent until a satisfactory result is obtained (Fig. 3). Several series have

shown successful acute intracerebral revascularization using balloon angioplasty alone [37] or in combination with chemical thrombolysis [38] and stenting [13,39].

Ultrasound augmentation of chemical thrombolysis

EKOS small vessel ultrasound infusion system

The EKOS MicroLysUS infusion catheter (EKOS Corporation, Bothel, Washington) is a 2.5-French microcatheter with a distal 2-mm, 2.1-MHz sonographic ring transducer at the tip designed to enhance intra-arterial chemical thrombolysis [40]. A guidewire is passed through the thrombus, and the microcatheter is guided into the proximal portion of the clot using standard technique. Once the guidewire is retracted, the system is activated and thrombolytic is infused through the microcatheter. Ultrasound is transmitted for the first 60 minutes of the infusion. The emitted high-frequency and low-intensity sonographic pulse waves help to modify the thrombus by increasing the surface area for fibrinolysis. Ultrasonic vibration creates local cavitation by producing convection currents and microstreaming at the surface of the thrombus. In the phase I North American Multicenter Safety and Efficacy Trial of the MicroLysUS device [40], 14 AIS patients with a mean NIHSS score of 18 (range: 9–27) were treated. Thrombolysis in myocardial ischemia (TIMI) grade 2 to 3 flow was attained in 57% of patients in the first hour, with a mean revascularization time of 46 minutes. Functional outcome at 3 months included an NIHSS score improvement of 10 points or more and a modified Rankin Scale (mRS) score of 2 or less in 5 of 8 surviving patients.

Ultrasound-enhanced systemic thrombolysis

Despite the loss of 65% to 90% of acoustic energy when 2-MHz ultrasound is transmitted through temporal bone [41], experimental evidence indicates that transcranial Doppler (TCD) ultrasound can enhance intravenous tPA-mediated thrombolysis by increasing drug transport into the clot, diminishing fibrin polymerization, and facilitating tPA binding to fibrin [42,43]. In the phase II CLOTBUST trial [43], 126 AIS patients with a mean NIHSS score of 17 were treated with intravenous tPA and randomized to continuous 2-MHz TCD ultrasound or placebo. Eligible patients had TCD evidence of MCA occlusion. Insonation depths of 35 to 45 mm were used for distal MCA (M2) occlusion, and those of 45 mm or greater were used for proximal MCA (M1) occlusion. FDA-approved pulsed-wave diagnostic TCD transducers were stabilized over the temporal bone using a standard head frame, and TCD monitoring was instituted for 2 hours. Within 2 hours of tPA administration, 49% of TCD-treated patients had complete recanalization or dramatic clinical recovery (defined as an NIHSS score ≤ 3 or ≥ 10-point improvement) compared with 30% of control patients ($P = 0.03$). Reocclusion was similar in both groups (18% in TCD-treated patients versus 22% in controls). Clinical benefit was abolished at 24 hours; however, a trend toward nondisabled functional outcome (mRS score of 0 or 1) was apparent at 3 months.

Indications and patient selection

Mechanical embolectomy is indicated for AIS patients with significant neurologic deficits who (1) present after 3 hours from symptom onset and thus are not candidates for intravenous tPA, (2) present within 3 hours from symptom onset and have contraindications for systemic tPA, (3) fail to recanalize or to significantly recover clinically after systemic thrombolysis, and (4) have an angiographically demonstrable occlusion of an accessible vessel, including the ICA; M1 or M2 MCA branches; and vertebral, basilar, or posterior cerebral arteries. What constitutes a significant neurologic deficit is debated, because different studies use different minimum NIHSS scores as inclusion criteria. The MERCI investigators [21,22] used an NIHSS score of 10 or greater, and the North American EKOS MicroLysUS trial [40] chose an NIHSS score of 8 or greater as a selection condition. In contrast, a minimum NIHSS score of 4 was chosen by the PROACT II investigators [9] and the phase I study of the EPAR laser system [28]. Additionally, some patients with large-vessel occlusion have minimal, transient or fluctuating symptoms at first presentation as a consequence of adequate collaterals that are maximally autoregulated but then deteriorate clinically as cerebral blood flow fails. Patients with isolated aphasia or neglect attributable to proximal MCA occlusion or stenosis may not qualify for endovascular therapy based on NIHSS criteria; yet, a large area of cerebral tissue may be at risk for infarction if percutaneous intervention is not instituted.

The advantage of noninvasive imaging modalities for selecting optimal patients for endovascular therapy is debated. Theoretically, to obtain maximal clinical benefit of revascularization, patients should have a small infarct core with a large


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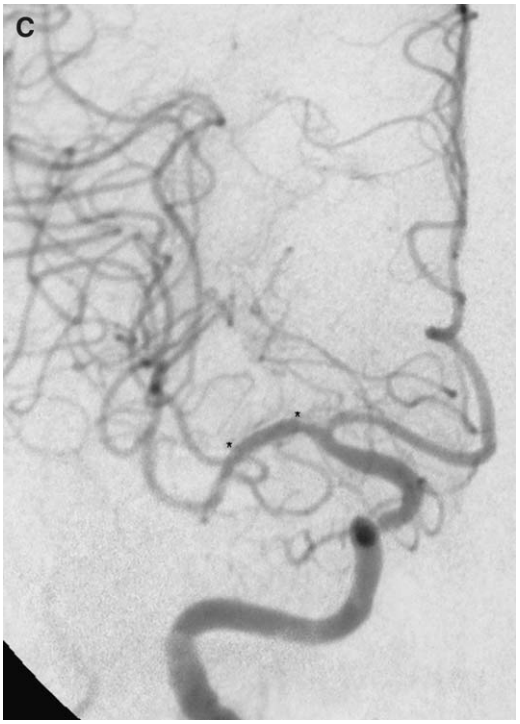
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perfusion deficit (penumbra) that would benefit from reperfusion. Two main imaging modalities are currently being investigated and used in clinical practice for this purpose. These have the potential to eliminate the thrombolytic time window and replace it with the tissue window.

MRI acute stroke protocol

Multiparametric MRI stroke protocols combining diffusion-weighted imaging (DWI), perfusion-weighted imaging (PWI), and magnetic resonance angiography (MRA) are useful at identifying tissue at risk [44]. DWI is more sensitive than CT at identifying early infarcted brain tissue (infarct core) [45]. Conflicting data indicate that DWI abnormalities may be reversible in up to 45% of patients after revascularization [46,47]. This reversibility is frequently partial and not permanent and may be dependent on a threshold apparent diffusion coefficient value [47,48]. Combined with vessel occlusion on MRA and PWI qualitative measurement of cerebral blood flow (CBF), a DWI/PWI mismatch can identify tissue at risk and is predictive of which patients are likely to achieve the most benefit from thrombolysis [49] even when intravenous thrombolytic is given up to 9 hours from stroke onset [50]. A DWI/PWI mismatch is evident in nearly 70% of patients imaged within 6 hours from stroke onset [44]. In the absence of a mismatch, patients are less likely to benefit from revascularization. In a retrospective analysis of MERCI penumbra data on 23 patients, the presence of a DWI/PWI mismatch of 20% or greater (14 patients) was associated with clinical benefit from revascularization based on 30-day mRS score (mean mRS score of 1.3 versus 5 in patients with and without a mismatch, respectively) [51]. MR Rescue, a multicenter prospective trial, is currently randomizing patients to endovascular revascularization with the Merci Retriever versus conservative management after stroke protocol MRI. The study intends to determine whether the presence of a DWI/PWI mismatch of 20% or greater is predictive of outcome in patients revascularized using the Merci device. In addition to DWI/PWI mismatch, recent data indicate that a clinical/DWI mismatch is predictive of early neurologic deterioration and infarct growth [52]. At our institution, we tend to prefer the combination of MRA and a clinical/DWI mismatch before mechanical embolectomy if the patient arrives more than 3 hours from AIS onset. The disadvantages of MRI include slow acquisition time, patient contraindications (ie, cardiac pacemaker), the need for patient tolerance (ie, claustrophobia, patient movement, clinical instability), and the lack of widespread availability.

CT acute stroke protocol

CT angiography (CTA) and CT perfusion imaging (CTP) do not have the same restrictions as MRI, require similar postprocessing times, and are universally available. Unlike PWI, CTP offers quantitative measurements of CBF, mean transit time, and cerebral blood volume (CBV) but is limited to only four brain slices and thus can miss zones of infarction. Threshold values for CTP parameters allow excellent assessment of the infarct core and penumbra [53]. CTA and MRA have equal accuracy in detecting vessel occlusion, and CTA source images significantly correlate with abnormalities on DWI [54]. When windowed appropriately, CTA source imaging is a good estimate of CBV and is useful at delineating the extent of tissue infarction. Disadvantages of CT stroke imaging are the need for intravenous contrast and large-bore intravenous access and the limited scope of CTP acquisition.

At our institution, use of MRI- or CT-based stroke imaging depends on the particular characteristics of the case. Regardless of the time window, if a significant infarct/perfusion mismatch is observed, we generally attempt mechanical embolectomy with or without chemical thrombolysis because of the presumed lower risk of reperfusion ICH. Whether or not patients with a well-defined infarct on DWI or CTA source imaging benefit from mechanical embolectomy, even if they arrive within a few hours of stroke onset, is not clear.

Fig. 3. A 69-year-old woman with known right MCA stenosis presented with worsening left hemiparesis and was treated with intravenous heparin and induced hypertension with symptom improvement. Marked hypoperfusion was still found by CT perfusion on hypertensive therapy, however. (*A*) Digital subtraction angiogram disclosed right MCA occlusion (anteroposterior view, right carotid injection). (*B*) Balloon angioplasty was performed, followed by stent placement. (*C*) Intracranial stent deployment maintained a patent MCA (* demarcates stent borders).

Risks of mechanical embolectomy

Reperfusion hemorrhage

The predominant risks of mechanical embolectomy are related to reperfusion injury or to complications of the endovascular device. Extrapolating from intra-arterial thrombolysis studies, the presence and extent of reperfusion hemorrhage after revascularization depends on several factors, including the duration and degree of ischemia; the size and location (ie, basal ganglia involvement) of the infarct core; the pretreatment NIHSS score; and the clinical propensity of the patient for bleeding, including inherent or iatrogenic coagulopathy, uncontrolled hypertension, hyperglycemia, and the existence of previous microhemorrhages on gradient echo MRI [12,55,56]. Whether any of these markers translates into the risk of reperfusion hemorrhage after mechanical embolectomy is not known. Anecdotally, pretreatment use of intravenous tPA or concurrent infusion of intra-arterial thrombolytic or GP IIb/IIIa inhibitors increases the risk of ICH with mechanical embolectomy, although the detrimental contribution of intra-arterial GP IIb/IIIa inhibitor seems to be negligible in most series [13]. In the combined MERCI I and II data, symptomatic ICH occurred in 9% of patients and was most commonly subsequent to ICA/ICA-T revascularization (17%) compared with 6% in MCA procedures and 0% in vertebrobasilar procedures [22]. Limited data on angioplasty and stenting for AIS provide reperfusion hemorrhage rates of 0% to 13% [37–39]. Symptomatic ICH complicated EPAR laser treatment in 6% of 34 patients [28]. There was no difference in the symptomatic ICH rate between TCD- and non-TCD–treated patients in the CLOTBUST study [43]. Mortality consequent to symptomatic reperfusion hemorrhage after endovascular intervention is dismal, reaching 83% in the PROACT II trial [55].

Device-related complications

Complications of mechanical embolectomy devices can be categorized as angiography related or device related. The rate of complications and how effectively they are managed depend on the experience of the operator. Adverse events include failure to deploy the device, device fracture, vessel dissection, arterial perforation, vasospasm, thromboembolism to an uninvolved arterial territory, cardiac arrhythmia (particularly bradycardia), and allergic reaction to contrast dye. Device-related complications occurred in 5.7% of 141 Merci Retriever–treated patients, and half of these represented anterior cerebral artery embolization from MCA revascularization [22]. The EPAR laser could not be deployed successfully in 35% of 34 patients, and 1 patient had a fatal outcome from device-related vessel rupture [28]. The EKOS MicroLysUS catheter was associated with one device failure from a cracked sonography element among 14 AIS treatments [40]. Arterial dissection occurred in 6% and asymptomatic thromboembolism events occurred in 11% of 18 patients treated with intracranial angioplasty [13]. These individual series data indicate that mechanical embolectomy is associated with a low risk of symptomatic device and angiography-related complications and, importantly, that few patients are worse off after endovascular intervention for AIS.

Summary

Mechanical embolectomy devices for AIS are advancing rapidly in design and indications for use. Currently, the Merci Retriever is the only FDA-approved device for clinical use in AIS. In the near future, the endovascular armamentarium should continue to expand as existing embolectomy devices are enhanced, novel devices are developed, and prospective trials to demonstrate efficacy and safety are performed and completed. Additionally, the expanding use of MRI- and CT-based stroke protocols should help to broaden the numbers of patients eligible for AIS intervention and improve patient selection. Hopefully, this will translate into improved clinical and functional outcomes by simultaneously diminishing reperfusion hemorrhage and augmenting the extent of cerebral tissue preservation.

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