Mechanical Revascularization Using the Reversal of Flow Method

This new device may help to prevent distal embolization during mechanical treatment of acute stroke.

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Stroke is the third leading cause of death and the first leading cause of major disability in the US. It affects approximately 750,000 Americans every year.[1] A large proportion of these patients, at least 40%, have an acute, large-artery, thromboembolic occlusion.[2] Unlike patients with acute myocardial infarction, most patients presenting with large-vessel intracranial occlusions have no underlying intracranial atherosclerotic disease.[3] One contributing factor to the lack of *in situ* thrombosis may be the high levels of diastolic flow in the cerebral vasculature—up to 40% of systolic.

At present, the only accepted and approved treatment for these patients is intravenous (IV) alteplase initiated within 3 hours of the occurrence of ischemic stroke.[4] However, fewer than 3% of patients presenting with stroke are being treated with alteplase.[5] One major factor contributing to this low percentage is that many patients present beyond the 3-hour window for infusion.[6] Beyond that time frame, results are not significantly different from conservative treatment, and the incidence of hemorrhage increases.[7,8]

There are two potential advantages of intra-arterial infusions of fibrinolytic agents over IV infusions. First, *in situ* catheter-directed thrombolysis is more effective in achieving recanalization for large thrombi than are IV infusions.[3,9,10] Second, the time window may be longer with this technique. One small trial of intra-arterial thrombolysis—the Pro-ACT 2 study—has shown a benefit in patients treated out to 6 hours after onset.[3] The major limitations of intra-arterial thrombolysis are the increased time for delivery, the length of time required to achieve recanalization by infusion alone, and the increased incidence of intra-cranial bleeding. A final limitation is incomplete effectiveness—30% to 40% of patients do not respond to intra-arterial infusions of lytic agents alone.[3]

MECHANICAL REVASCULARIZATION

The most promising approach for improving the outcome of these patients is mechanical revascularization. Mechanical revascularization of the brain is possible using special wires, balloons, and other retrieval devices.[11-13] The major advantages of mechanical techniques are the speed of revascularization relative to infusions of lytic agents and the potential reduction in symptomatic hemorrhage after

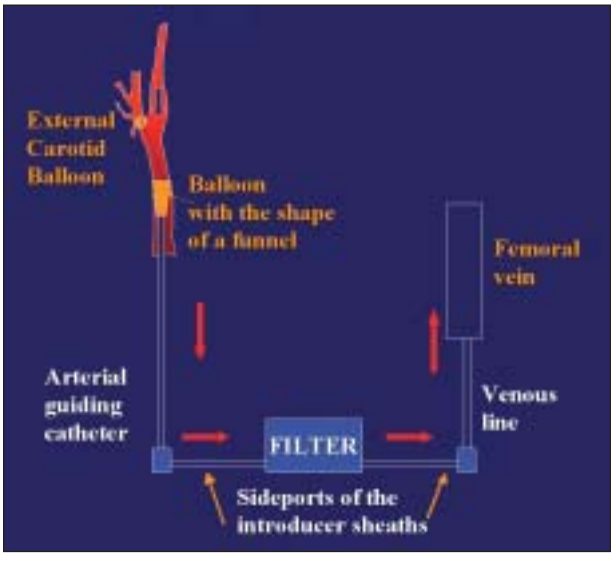

Figure 1. Parodi Antiembolism System (PAES) in position.

establishing reperfusion. The most significant limitation is distal embolization of particles resulting from manipulation of the occluding material in a setting of antegrade perfusion. This phenomenon occurs regularly after attempts of mechanical treatment of middle cerebral artery (MCA) occlusion. Yoneyama et al reported that distal embolic occlusions ensued after angioplasty in 10 of the 15 cases of MCA occlusion treated mechanically.[14]

We have designed our own device, the Parodi Antiembolism System ([PAES] ArteriA Medical Science Inc., El Presidio, CA), according to a new concept that ensures cerebral protection by producing retrograde ICA flow at the time of lesion crossing, angioplasty, and stent deployment achieved by balloon occlusion of the common carotid artery (CCA) and the external carotid artery (ECA).[15] This device and concept combination also has applications for intracranial mechanical revascularization techniques, as will be discussed subsequently. ICA flow reversal is achieved with a carotid-to-femoral arteriovenous shunt connecting the guiding catheter to a femoral vein introducer (Figure 1). This shunt can be supplemented with aspiration through the guiding catheter, especially when the stent deployment device is introduced. The principle of this system was extensively explored in animal models before embarking in clinical cases.[16]

DEVICE DESCRIPTION

The PAES is a closed system that allows ICA flow arrest, continuous passive ICA flow reversal, or augmented active ICA flow reversal, such that any particles released during carotid artery stenting (CAS) will pass retrograde through the catheter to be retrieved in the arteriovenous conduit filter outside the body. The three components of the

Figure 2. Funnel-shaped balloon at the end of the PAEC.

device were specifically designed to allow retrograde laminar flow in the ICA and minimize margination of particles or collection of material that could subsequently embolize.

1. PAEC (Parodi Antiembolism Catheter): The PAEC is a 10-F guide catheter with a funnel-shaped balloon on the tip (Figure 2). This atraumatic balloon allows the occlusion of the CCA and flow reversal. It also serves as the access port for the stent delivery system and other therapeutic devices. Smaller-diameter catheters are in development.

2. PEB (Parodi External Balloon): The PEB is a soft atraumatic oval balloon mounted on a 0.019-inch hypo tube. The distal shapeable, floppy guidewire facilitates easy navigation into the ECA.

3. BRS (Blood Return System): The third component is a conduit that connects the side flow reversal port of the PAEC to a venous sheath. This conduit contains a 180-µm filter that collects particulate debris before the blood reenters the venous system.

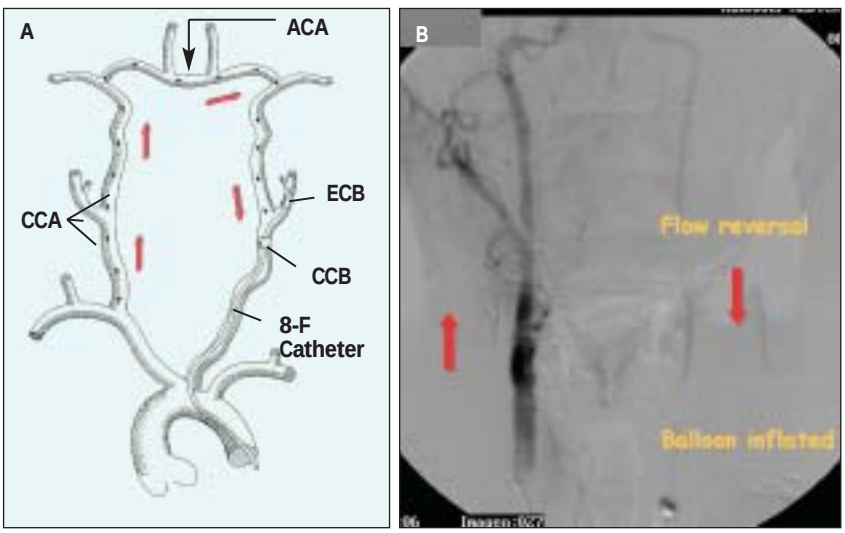

Figure 3. Flow reversal (A) is demonstrated in this arteriogram (B) injecting contrast in the contralateral carotid artery.

FLOW REVERSAL TECHNIQUE

The first step is the placement of the PAEC. This can be done using any of the accepted techniques for guide catheter placement in the carotid artery. The PEB is then placed through the dedicated proximal port of the PAEC and navigated under fluoroscopic guidance into the ECA. The third step is purging and attaching the BRS to a 6-F venous sheath. The venous sheath can be placed in the ipsilateral or contralateral femoral vein.

Once the device is in position, the CCA is occluded with the PAEC and

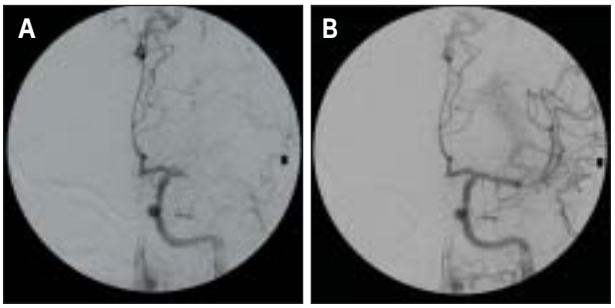

Figure 4. Arteriogram showing complete occlusion of the MCA (A). Arteriogram after mechanical revascularization under flow reversal; normal flow was re-established (B).

the PEB is inflated in the ECA. Opening the BRS stopcock initiates continuous flow reversal through the arteriovenous shunt (Figure 3A,B).

For the intracranial application of the reversal of flow system, only the PAEC is needed provided that the carotid bifurcation is normal. The PAEC can be placed directly in the ICA.

In February of 2003, at the 28th International Stroke Meeting in Phoenix, we presented our experience in 83 patients in whom we used the PAES during CAS.[17] These patients were evaluated using transcranial Doppler monitoring and dynamic intracranial angiography. Reversal of flow in the MCA was achieved in 72% of the patients when the system was applied and the connection of the side port of the venous line was established (Figure 4). In 89%, active aspiration produced the desired effect, but in 11% of the patients, ancillary maneuvers were needed. Ancillary maneuvers consisted of compression of the contralateral CCA to abolish anterior communicating artery flow from the contralateral side. That flow maintained MCA antegrade flow. In one case, external compression of the vertebral artery was needed to interrupt antegrade flow in the MCA. The conclusion of the study was that we were able to stop the antegrade flow and produce retrograde flow in the MCA in every patient we studied.

We are actively investigating the hypothesis that by interrupting the antegrade flow and promoting retrograde flow in the middle and anterior cerebral arteries, we can achieve mechanical revascularization of the distal internal carotid bifurcation or the proximal middle or anterior cerebral arteries, without allowing distal embolization. This technique entails a mechanical disruption of the thrombus in the setting of flow reversal, facilitating the removal of particles by aspiration. One promising adjunctive therapy is the infusion of cold saline to achieve local hypothermia—a proven brain-protection technique—prior to initiating flow reversal.

CONCLUSION

The PAES device can be used to reverse flow in the intracranial circulation and may be valuable in preventing distal embolization and facilitate removal of thrombi during mechanical transcatheter acute stroke treatment. ■

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