A Novel Device for the Revascularization in Acute Ischemic Stroke Patients

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Summary

This article provides insights into how the authors developed the Solitaire™ FR revascularization device and associated procedure including commentary on the mechanism of revascularization and future of device development in this area. The article is intended to give research-minded physicians a view into the device development world by sighting examples of this novel device for revascularizing patients with acute ischemic stroke.

History of Disease State

According to the American Heart Association, stroke is the third leading cause of death and the leading cause of serious, long-term disability in the United States¹. Each year, approximately 795,000 people experience a new or recurrent stroke¹. Approximately 87% of the strokes occurring in the United States are categorized as ischemic¹. Ischemic strokes due to large intracranial vessel occlusions have a higher mortality rate, estimated between 53% to 92%^{2,3}. Recent studies have shown a strong correlation between improved neurological outcomes and recanalization of the occluded vessel, particularly with faster times to recanalization of the vessel from stroke onset⁴. However, there are currently few treatments for acute ischemic stroke and even fewer options to achieve efficient and fast recanalization with the potential for improved neurological outcomes. The recanalization rates of intravenous

(IV) thrombolysis with recombinant tissue plasminogen activator (rtPA, altepase) for large vessel occlusion range from only 10% for internal carotid artery (ICA) occlusion to 30% for proximal middle cerebral (MCA) occlusion^{4,5}. Intrarterial (IA) thrombolysis technique has led to higher recanalization rates than IV thrombolysis⁵. However, the limited time window, increased risk of intracerebral hemorrhage, longer recanalization times, and uncertain efficiency in lysing with all clot types limit the number of patients eligible to receive thrombolytics and successful recanalization^{4,5}. Mechanical clot removal has improved recanalization rates and has increased the treatment options for patients. The Merci Retriever, by Concentric Medical, approved by the FDA, has performed two clinical trials, the most recent being the Multi MERCI trial, which showed revascularization rates of 57.3% with the device alone and 69.5% with the device combined with IV or IA therapy³.

The Penumbra system, approved by the FDA, removes the thrombus by debulking and aspiration and with its most recent clinical trial, the Penumbra Pivotal Stroke Trial, resulted in revascularization rates of 81.6%, but at 90 days only 25% of patients had good outcomes⁷. Early clinical experience with self-expanding stents has shown high revascularization rates, from 79% to 100%⁴. However, the limitations to using the current self-expanding stents, such as Neuroform, Enterprise, Wingspan and Leo, include permanent implantation, antiplatelet drug therapy, off-label use and increased intracranial hemorrhage risk.

History of Device

ev3 Inc. started to focus on the development of innovative stroke intervention devices several years ago. Of the various devices tested, the Solitaire™ FR revascularization device showed the most promising design platform for treatment of acute ischemic stroke. The luminal design allows for the potential to restore flow upon deployment of the device across the clot, thus permitting blood flow to reach the compromised brain tissue quickly. In the initial studies with the Solitaire™ FR revascularization device, the procedure focused on obtaining flow restoration and it was theorized that the natural lytic properties of the blood would facilitate dissolution of the blood clot. Results showed that these mechanisms were unable to fully dissolve the clot in the animal model. However, it was discovered that the Solitaire™ FR revascularization device was highly effective for clot retrieval. The procedure with the Solitaire™ FR revascularization device still provides the benefits of the potential for flow restoration as well as effective and safe clot retrieval.

The Solitaire™ FR revascularization device has a CE mark and is undergoing a clinical study under an Investigational Device Exemption (IDE) approved by the United States Food and Drug Administration. The clinical study, named SWIFT (Solitaire FR With Intention For Thrombectomy), began enrolling patients in February 2010 and is the first device-based randomized clinical study for revascularization in patients having an acute ischemic stroke.

Device Design/Uniqueness of Design and Procedure/Strategy

The Solitaire™ FR revascularization device is a self-expanding, retrievable stent-like neurovascular device designed to restore blood flow in patients experiencing ischemic stroke due to large intracranial vessel occlusion. The Solitaire™ FR revascularization device is available in 4 mm and 6 mm diameters and in lengths ranging from 15 mm to 30 mm. The Solitaire™ FR revascularization device is designed to treat vessels with diameters ranging from 2.0 to 5.5 mm, such as the internal carotid artery, M1 and M2 segments of the middle cerebral artery, anterior cerebral artery, basilar artery and vertebral artery, and clot lengths up to 30 mm. Device diameters of 4 mm and 6 mm are com-

patible with size 18 (inner diameter is approximately 0.021") and size 027 microcatheters (inner diameter is approximately 0.027"), respectively. The Solitaire™ FR revascularization device has proven ease of navigation to the distal neurovasculature.

The Solitaire™ FR revascularization device procedure is simple and fast. First, the microcatheter is positioned across the clot so that when the Solitaire™ FR revascularization device is fully deployed, it will extend past both ends of the clot. Next, the Solitaire™ FR revascularization device is delivered through the microcatheter until the distal radiopaque markers have reached the end of the microcatheter. To deploy the device, the push wire is held fixed to maintain the position of the device while the microcatheter is retracted proximally to the proximal marker of the Solitaire™ FR revascularization device. At this point, the luminal design of the Solitaire™ FR revascularization device with optimum radial force allows for the potential for flow restoration. With this created channel, blood flow can reach the ischemic brain tissue quickly. This channel increases the exposed surface area of the clot to blood flow, which may be beneficial to those patients with failed IV t-PA therapy and can also provide the physician with time to administer pharmacological therapy if desired (only for countries with CE mark). In theory, the additional exposed surface area of the clot with medical therapy could assist with dissolution of the clot. An additional benefit of the Solitaire™ FR revascularization device is the ability to retrieve it into the microcatheter after full deployment, then re-reposition and re-deploy it again if necessary. The final step of the procedure is to retrieve the fully deployed device with the clot into the balloon guide catheter under aspiration. Upon deployment, in addition to the advantages of flow restoration and additional exposed surface area of the clot to the flow, the optimum radial force allows for the device to penetrate the clot, promoting adhesion of the clot to the device, and release of the high pressure gradient across the clot, promoting dislodgement of the clot from the vessel wall. The unique large cell design of the Solitaire™ FR revascularization device allows for continuous retention of the clot to the device upon deployment to retrieval into the guide catheter as well as high circumferential conformability, flexibility, and axial rigidity. All of these properties of the device contribute to successful clot retrieval.

Figure 1 Solitaire™ FR Revascularization device with a retrieved clot.

Impact on the Field

This novel device offers physician and patients a multitude of advantages compared to the current treatment options and has the potential to become the primary therapy for acute ischemic stroke. The Solitaire™ FR revascularization device has an extremely simple, fast, efficient and safe procedure with the potential for high recanalization rates and improved neurological outcomes. The Solitaire™ FR revascularization device is the only luminal thrombectomy device to provide the potential for flow restoration upon deployment, multimodality use (temporary bypass, administration of pharmacological therapy, and clot retrieval), and effectiveness of complete retrievability to remove the occlusion.

Future Directions

Fast recanalization of occluded vessels in acute ischemic stroke is highly correlated to improved neurological outcomes⁴. As awareness and acceptance of this correlation in the stroke community continues to grow, the future direction of acute ischemic stroke treatment options is headed toward mechanical thrombectomy devices with fast and effective recanalization as well as combined use of mechanical thrombectomy and pharmacological therapy. Future modifications to mechanical thrombectomy devices may be directed toward treating more distal vessel occlusions, improved clot retention and clot composition-based device designs.

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