Flow Diversion for Intracranial Aneurysms

A brief look at the development of these devices and their potential utility in the treatment of intracranial aneurysms.

BY GIUSEPPE LANZINO, MD

In the spring of 2011, the US Food and Drug Administration approved the Pipeline embolization device (Covidien, Mansfield, MA) for the endovascular treatment of complex intracranial aneurysms localized in the paraclinoid internal carotid artery, potentially ushering in a new era in the treatment of intracranial aneurysms. The introduction of flow diverters for clinical use is the culmination of a long development period that started 20 years ago.[1,2] The development of these devices is a classic example of an idea based on theoretical and in vitro studies, confirmed by animal experiments and eventually reaching the clinical arena.

In the early 90s, sophisticated in vitro studies using laser flow models suggested that a stent placed across the orifice of an aneurysm could disrupt flow patterns and redirect flow away from the aneurysm back into the parent artery. This flow disruption in turn would promote intra-aneurysmal stasis and eventually thrombosis of the aneurysm (Figure 1).

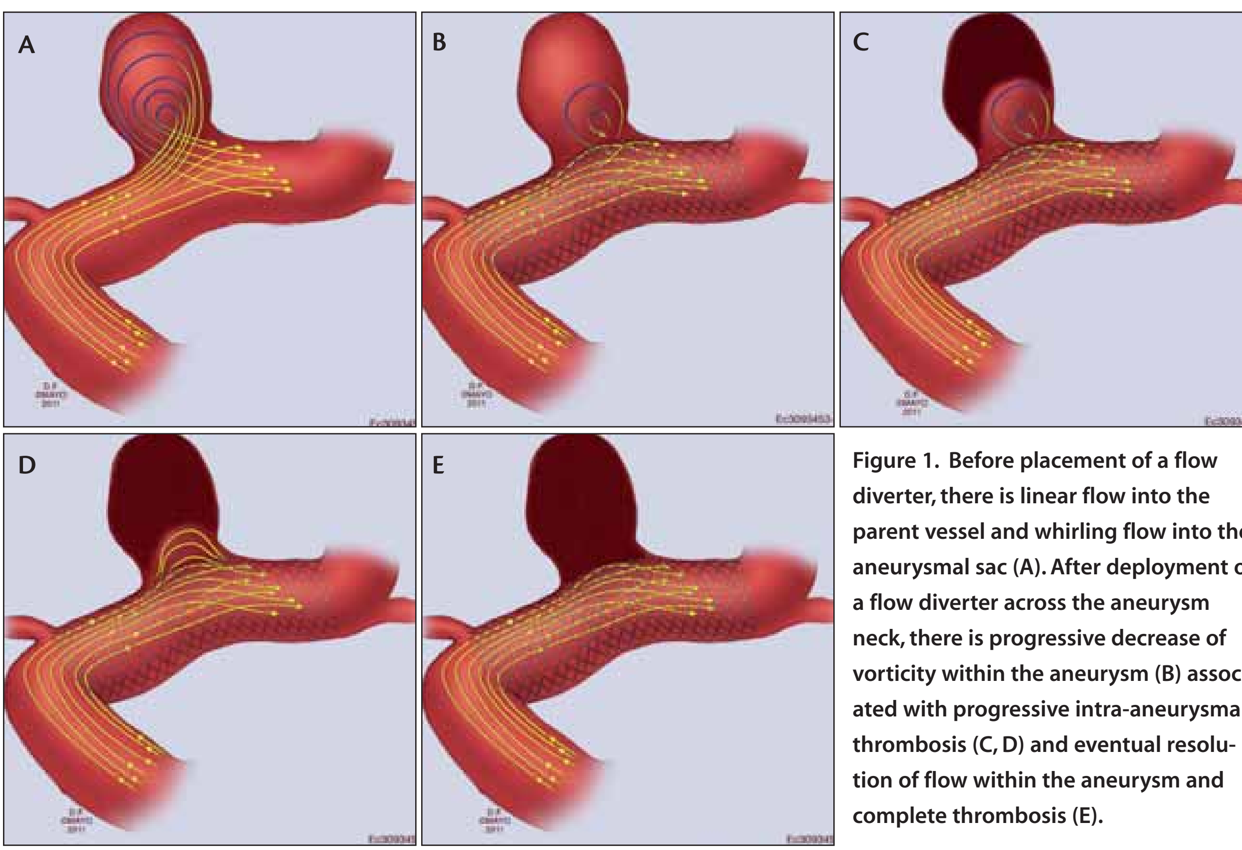

Figure 1. Before placement of a flow diverter, there is linear flow into the parent vessel and whirling flow into the aneurysmal sac (A). After deployment of a flow diverter across the aneurysm neck, there is progressive decrease of vorticity within the aneurysm (B) associated with progressive intra-aneurysmal thrombosis (C, D) and eventual resolution of flow within the aneurysm and complete thrombosis (E).

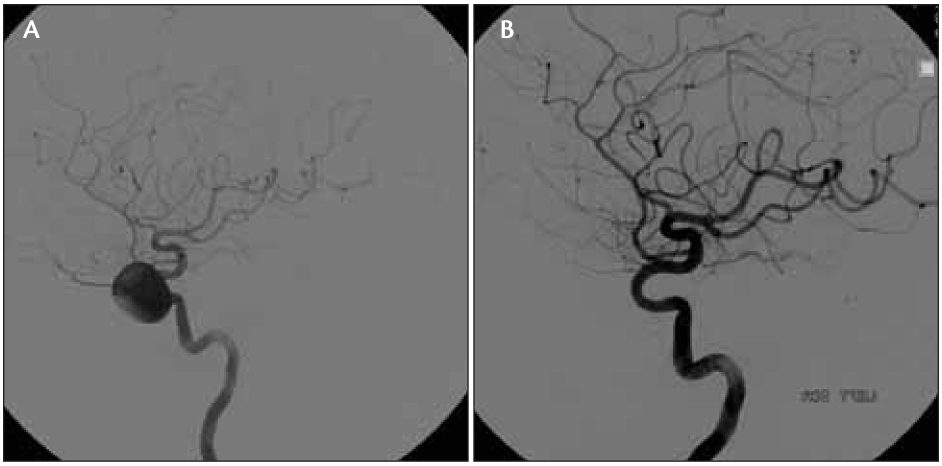

Figure 2. This 67-year-old woman had an imaging study for evaluation of progressive memory dysfunction. She was found to have an incidental, very large, left cavernous sinus aneurysm (A), which was treated with the Pipeline embolization device. Follow-up angiography 6 months later shows complete angiographic obliteration of the aneurysm and patency of the parent vessel (B).

These theoretical concepts were confirmed by animal studies, which showed aneurysm thrombosis and angiographic obliteration after placement of a stent across side-wall experimental aneurysms. Clinical application of these concepts was limited by the high porosity of stents available for clinical use. Therefore, first-generation intracranial stents were used mostly as adjuncts during coiling of wide-neck aneurysms. In these cases, the stent acted as a scaffold, preventing coil herniation into the parent vessel during endovascular treatment of complex aneurysms with a wide neck.

The development of newer endovascular stents delivered through a microcatheter and flexible enough to be navigated through tortuous intracranial circulation led the way to the refinement of flow diverters for clinical use. These devices have low porosity and the ability to change hemodynamic forces and vectors in the segment bearing the aneurysm.

Animal studies have shown that treatment of an experimental aneurysm with flow diverters resulted in intra-aneurysmal stasis and progressive thrombosis of the aneurysm with subsequent clot organization, retraction, and eventually actual shrinkage of the aneurysm.[3] Moreover, as the device works as a scaffold for endothelialization, a neointima is formed across the aneurysm neck, securing complete and permanent angiographic obliteration. More importantly, these earlier animal studies with first-generation flow diverters have shown that side branches emanating from the treated arterial segment tend to stay open, as flow in these branches is secured by a pressure gradient.

Early clinical series have been encouraging with high rates of complete obliteration despite the high complexity of the aneurysms treated (Figure 2). In a multicenter study conducted in Europe and South America, rates of complete obliteration as high as 93% were observed at 6 months,[4] and these encouraging results have been confirmed by single-institution series.[5,6]

Despite these early positive clinical results, several questions still remain unanswered. These are related to the issue of early aneurysm rupture after treatment while thrombosis occurs, the need for dual-antiplatelet therapy, the fate of side branches and critical perforators that arise from the treated arterial segment, and the long-term patency of the devices. Moreover, the mechanism of action (progressive but not instant aneurysm obliteration) would limit use of these devices primarily to unruptured aneurysms. While early clinical series and our own experience confirm safety and efficacy for aneurysms located in the internal carotid artery proximal to the origin of the posterior communicating artery, we do not know at the present time how flow diverters will perform in other territories. Interventionists at many any centers in the United States are now being trained for use of these devices, and with large-scale use, we soon will know their real role in the modern treatment of intracranial aneurysms. ■

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