Current endovascular treatment options for intracranial carotid artery atherosclerosis

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A substantial number of strokes are caused by intracranial atherosclerosis, a disease that traditionally has been treated medically. Recent technological advancements, however, have revolutionized the treatment of this condition by enabling the use of endovascular methods. In this paper the authors focus on the internal carotid artery, and review relevant studies concerning angioplasty with stent placement for the management of intracranial atherosclerosis in this vessel. With continued experience and a multidisciplinary approach in the evaluation of these patients, favorable outcomes may be achieved.

KEY WORDS • carotid artery • atherosclerosis • endovascular treatment • interventional neuroradiology • intracranial lesion • stenosis

LITERATURE REVIEW

Technological advancements, such as angioplasty with stent placement, have expanded the current catalog of diseases amenable to endovascular treatment. Although angioplasty with stent placement is increasing in popularity and has shown encouraging results, this procedure remains technically demanding and carries substantial risks of illness and death. More specifically, balloon angioplasty may cause thromboembolism, vascular dissection with acute or delayed occlusion, pseudoaneurysm formation, vessel rupture, and occlusion of small perforating vessels.2,8,15,24 Previous studies have shown the rate of procedure-related stroke to be 8 to 50% and that of vascular dissection to be 38%.2,8,15,24 With this in mind, endovascular treatment should be reserved for those patients in whom maximal medical management fails.

Patient Selection

Proper patient selection for endovascular treatment of intracranial atherosclerosis is critical in obtaining favorable outcomes. Identifying individuals who would most benefit from treatment should involve a thorough preoperative evaluation by an experienced clinician to correlate signs and symptoms accurately with the presumed vessel of interest. Furthermore, other potential diagnoses must be excluded. Treating physicians must also take into consideration the anatomical configuration of the lesion as well as the patient’s neurological and hemodynamic status. For instance, an acute stroke combined with perfusion failure creates a difficult circumstance in which the risk of perioperative complications is extremely high, approaching nearly 50%.4,9 In such patients, acceptable outcomes may be obtained with medical management alone, and the potential for adverse events associated with cerebral revascularization must be weighed against the possibility of recurrent or progressive cerebral ischemia.

Abbreviation used in this paper: ICA = internal carotid artery.
Underlying Pathophysiological Conditions

The pathophysiological conditions underlying clinical findings may also have an impact on outcome. Perfusion failure commonly presents with position-dependent neurological symptoms, much like an orthostatic reaction. Such patients need to be carefully differentiated from those whose symptomatology is caused by penetrating artery occlusion, because the latter are not likely to benefit from either angioplasty or surgical bypass. In addition, angiographically demonstrated stenosis is not sufficient to warrant intervention, because these radiographic findings must be hemodynamically significant before we can proceed with endovascular therapy.

Complexity of Lesions

The complexity of atherosclerotic lesions is another factor that plays an important role in the success of endovascular treatment. Mori and colleagues generated a classification system based on angiographic findings that may be used to predict outcome after cerebral revascularization accomplished with primary angioplasty alone. Using this classification, Type A lesions, which are short (≤5 mm long), concentric or moderately eccentric, and nonocclusive, have a treatment success rate of 92% and a 1-year critical restenosis rate of 0%. Type B lesions, which are tubular (5–10 mm long), extremely eccentric, and moderately angulated (curved), have a treatment success rate of 86% and a 1-year critical restenosis rate of 33%. Type C lesions, which are diffuse (>10 mm long), extremely angulated (>90°), and have a very tortuous proximal segment, have a treatment success rate of only 33% and a 1-year critical restenosis rate as high as 100%. These numbers demonstrate that worse immediate and long-term outcomes may be expected when treating complex lesions. Stent technology, however, addresses many of the limitations specific to angioplasty alone.

Angioplasty With Stent Placement

Stent-assisted technology may be used in conjunction with angioplasty to improve outcome by limiting vascular recoil and dissection. Stent placement also significantly reduces the rate of restenosis that may occur after balloon angioplasty, even in Types B and C intracranial lesions. Until recently, stent implantation had been reserved for use in the peripheral, extracranial cerebral, and coronary circulations because of technical limitations. Nevertheless, state-of-the-art models of the newer devices, which are lighter and more flexible than their predecessors, can be navigated through tortuous intracranial vessels. In addition, newer stents are composed of thin struts that are widely spaced, thereby decreasing the risk of occluding perforating vessels.

Although angioplasty with stent placement is theoretically applicable to the treatment of intracranial atherosclerosis, the safety and efficacy of this modality are controversial. In 2002, Levy et al. published a comprehensive literature review of endovascular stent treatment for intracranial atherosclerosis. At that time, evaluation of this method was limited to several small retrospective series in which varying complication rates were demonstrated. Additionally, these studies largely focused on posterior circulation atherosclerosis and lacked data regarding stenosis of the anterior circulation, including the ICA. Recently, a handful of studies have emerged that allow for a more complete assessment of endovascular stent treatment and reveal developments in this rapidly changing field.

Gupta, et al. retrospectively reviewed the efficacy of endovascular angioplasty with stent placement in intracranial stenoses in 18 neurologically unstable patients who were deemed to be at imminent risk for stroke. Twenty-one intracranial atherosclerotic lesions were urgently treated, eight of which were located in the distal ICA. The rate of major periprocedural complications in this cohort reached 50%, with 17% of patients experiencing intracranial hemorrhage, 11% suffering from disabling ischemic stroke, and 22% experiencing extracranial hemorrhage. The overall fatality rate in this review was 17% (three of 18) within 30 days. Although stent delivery and release were technically feasible in this study, treatment was associated with high complication and mortality rates.

On initial review, results from this study raise concerns about the safety of an endovascular approach to treat intracranial atherosclerosis. These rates of adverse events, however, should be considered in the context of the high-risk population studied: all patients were neurologically unstable individuals in whom maximal medical therapy had failed, and six had infarcts that were positive on diffusion-weighted imaging within 72 hours prior to the procedure. In addition, of the six patients treated for intracranial ICA stenosis, none died or experienced disabling stroke. Thus, while it is difficult to conduct a subcohort analysis with such a small number of patients, the favorable outcomes experienced in this study by patients with intracranial ICA atherosclerosis appear promising.

One major concern regarding intracranial stent delivery is the effect of stent placement across major branch arteries. Lopes, et al. recently addressed this issue in a retrospective angiographic review of 40 patients who received intracranial stents. When placed, the device crossed a major branch artery in 10 cases, three of which involved treatment of atherosclerotic stenosis. On follow-up angiographic studies, each branch artery remained patent and no ischemia was clinically detected. Although the number of patients in this study was small, it provides some evidence that stents may be placed across major branch arteries without deleterious effects.

Vascular dissection and rupture have been reported as a direct consequence of balloon angioplasty and stent placement in several cases. The development of smaller stents to prevent these complications has been proposed, and de Rochemont, et al. recently investigated the safety and efficacy of undersized stents in treating high-grade symptomatic intracranial stenosis. In this prospective study, 18 patients, seven of whom had intracranial ICA atherosclerosis, were treated with an undersized stent that was 0.5 mm smaller in diameter than the vessel. The 30-day combined incidence of death and stroke was 6%, with one patient suffering a parenchymal hemorrhage. At 6 months, no ischemic symptoms had developed. Notably, no cases of vessel dissection or rupture occurred. These results indicate that purposefully undersized stents may be safe and
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effective in the treatment of high-grade symptomatic stenosis. In this study the authors emphasize that the goal of treatment is to restore adequate cerebral blood flow, not to restore vessel diameter completely. Furthermore, the rate of restenosis is believed to be associated with the degree of intimal damage produced by balloon dilation.5 Considering that an increase in luminal diameter has an exponential effect on flow rate, adequate revascularization can be achieved without complete angiographically confirmed resolution of the lesion.

The recently published Stenting of Symptomatic Atherosclerotic Lesions in the Vertebral or Intracranial Arteries study21 is a prospective investigation of the safety and efficacy of one stent device, the NEUROLINK system, in 61 patients with symptomatic stenosis, 43 of whom were treated for intracranial disease. The NEUROLINK is specifically designed for the cerebral vasculature and contains a balloon dilation catheter, delivery catheter, and stent. The stent is made of stainless steel, with only a few links connecting the rings, which allows the device to be navigated through tortuous intracranial vessels with enhanced flexibility. In addition, the struts do not lift as the stent turns, thereby decreasing the chance of vessel wall damage. The stent was delivered successfully in 95% of the cases.

The rate of stroke in this study within 30 days of stent placement was four (6.6%) of 61 for all patients; two episodes occurred during the procedure, and none occurred in the anterior circulation. No deaths occurred within the first 30 days. Follow-up angiographic studies obtained at 6 months revealed restenosis (> 50% stenosis) rates of 32.4 and 42.9% in the intracranial and extracranial groups, respectively, the majority of which cases (61%) were asymptomatic. At 1 year, eight (13%) of 61 patients had suffered strokes, including six (14%) of 43 patients treated for intracranial lesions and two (13.3%) of 15 treated specifically for intracranial ICA stenosis. It should be noted that this study included only patients whose symptoms were attributable to a single target lesion. Thus, the results do not reflect cases of diffuse intracranial atherosclerotic disease. Nevertheless, this study provides much-needed prospective evidence that stent placement in intracranial ICA stenoses can be performed with high rates of success and relatively low rates of morbidity.

Novel stent technology likely represents just the beginning of the innovative approaches that will be used by endovascular neurosurgeons to treat intracranial atherosclerosis effectively. Further clinical studies, however, particularly a trial comparing stent placement to the best medical management available, are warranted to determine the efficacy and appropriateness of this technique.

**CONCLUSIONS**

Considering the poor prognosis of patients with intracranial ICA atherosclerosis, despite maximal medical management, interventional treatment options for this disease have gained popularity. Although conventional surgical revascularization with craniotomy has met with limited success, endovascular procedures have demonstrated tremendous therapeutic potential. Angioplasty with stent placement carries risks along with a significant rate of restenosis; however, advancements in technology and methodology have begun to address these issues. In short, endovascular methods have revolutionized the treatment of this disease. With continued experience and a multidisciplinary approach in the evaluation of these patients, favorable outcomes may be achieved.

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Manuscript received November 19, 2004. Accepted in final form December 6, 2004.

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