Endovascular stent repair of traumatic cervical internal carotid artery injuries

Gaurav Jindal, MD, Manuel Fortes, MD, Timothy Miller, MD, Thomas Scalea, MD, *and* **Dheeraj Gandhi, MD,** *Baltimore, Maryland*

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From the Division of Interventional Neuroradiology (G.J., M.F., T.M., D.G.), Department of Radiology, University of Maryland Medical System; and Department of Trauma Surgery (T.S.), R Adams Cowley Shock Trauma Center, University of Maryland, Baltimore, Maryland.
Address for reprints: Gaurav Jindal, MD, University of Maryland Medical System, Department of Radiology, 22 S. Greene St, Baltimore, MD 21201; email: drjindal@gmail.com.

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The role of endovascular repair of traumatic cervical internal carotid artery (ICA) injuries continues to evolve. The purpose of this report was to review pertinent background of carotid artery injury and the indications, device options, results, and complications associated with endovascular repair of traumatic cervical ICA injury.

INCIDENCE

Traumatic injury to the ICA has become a well-recognized phenomenon in the setting of blunt or penetrating trauma.[1–6] Multicenter reports from the prescreening era established a blunt vascular neck injury incidence of 0.1% to 0.17%, associated with a 67% delayed stroke rate and a 38% mortality.[7–9] Growing familiarity with the disease process and both recent advancements in and better availability of cross-sectional imaging has resulted in an increased awareness of internal carotid arterial injury. Schneidereit et al.[1] demonstrated a 1.1 % incidence of blunt vascular neck injuries in the setting of blunt trauma when screened with computed tomographic angiography (CTA). Berne et al.[6] showed high morbidity and mortality rates because of diagnostic delay before implementation of screening protocols to identify blunt cerebrovascular injuries at admission using CTA.

CLASSIFICATION

The Denver Grading Scale outlined by Biffl et al.[10] illustrates the spectrum of blunt cerebrovascular injury seen on CTA or digital subtraction angiography (DSA). This grading system has prognostic and therapeutic implications. Grade I represents mild intimal injury or irregular intima. Grade II injury is a dissection with a raised intimal flap or vessel thrombosis resulting in luminal narrowing greater than 25%. Grade III injuries have a dissecting aneurysm or pseudoaneurysm. Grade IV injuries represent vessel occlusion or thrombosis, while Grade V injuries represent vessel transection.

NATURAL HISTORY

The natural history of traumatic carotid dissection with or without a dissecting aneurysm is not well defined. Some reports suggest that blunt carotid injuries have been associated with mortality rates of 20% to 40% and permanent neurologic impairment in 40% to 80%.[11–13] Moreover, many traumatic dissections occur in the presence of other injuries, which may impact treatment and neurologic outcome. The majority of previously reported literature on the topic addresses the prognosis of spontaneous rather than traumatic cervical artery dissection. One such study demonstrated no ischemic complications in 33 dissecting aneurysms of the internal carotid arteries at a mean follow-up of greater than 3 years.[14] Another demonstrated minimal increase in annual stroke risk from 0.3% to 0.7% in a total of 46 patients with transient carotid stenosis versus 46 patients with persistent severe carotid stenosis, although the vast majority of patients in the persistent severe stenosis group presented with ischemic events.[15]

Although some small intimal injuries caused by trauma will respond well to conservative measures, blunt traumatic carotid arterial dissections have been shown to have a worse prognosis in comparison with spontaneous dissections. Biffl et al.[10] demonstrated that 20% of Grade II injuries resolved or improved at follow-up, while 80% persisted or worsened, with 75% developing aneurysms and 12.5% progressing to occlusion. Only 4% of Grade III injuries in that series went on to heal. Panetta et al.[16] have demonstrated that only up to a third

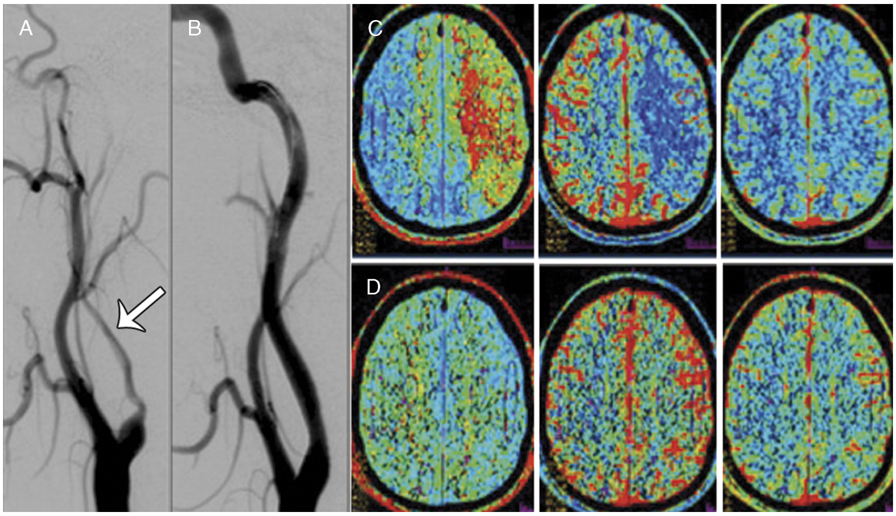

Figure 1. A 30-year-old with expressive aphasia, right hemiparesis after motor vehicle accident. Left common carotid injection digital subtraction angiogram demonstrates long segment vessel irregularity of the left ICA (arrow) compatible with long segment dissection (*A*). Poststent repair left common carotid injection digital subtraction angiogram (*B*) demonstrates resolution of left cervical ICA irregularity without disruption of blood flow (*C*). Axial head CT perfusion images before stenting through the mid cerebrum demonstrate delay in mean transit time and decrease in cerebral blood flow throughout the left cerebral hemisphere with relative preservation of cerebral blood volume, findings compatible with perfusional ischemia and tissue at risk of infarction. Axial head CT perfusion images (*D*) through the midcerebrum after stent repair of the left ICA demonstrate resolution of previously seen abnormalities in mean transit time and cerebral blood flow throughout the left cerebral hemisphere.

Figure 2. A 45-year-old status post–gunshot trauma to the neck. *A*, Diffusion-weighted magnetic resonance image through the upper cerebrum demonstrates focal diffusion restriction compatible with acute infarction within the posterior left frontal lobe (arrow). *B*, Digital subtraction angiogram upon injection of the left common carotid artery demonstrates focal narrowing of the midcervical left ICA compatible with dissection (curved arrow). *C*, Poststent repair left common carotid injection digital subtraction angiogram demonstrates resolution of dissection related narrowing without evidence of flow restriction within the left ICA.

of blunt carotid injuries resolve without subsequent complication. Fabian et al.[17] noted that 29% of these injuries progress to dissecting aneurysm on repeat imaging.

In comparison, spontaneous cervical arterial dissections have shown angiographic resolution or improvement in a greater number of cases. While the likelihood of angiographic recovery of a spontaneous cervical arterial dissection depends largely on the extent of the initial injury, approximately 90% of stenoses can eventually resolve, two thirds of occlusions can recanalize, and one third of aneurysms may decrease in size, according to some studies.[18–20]

The outcomes of traumatic and spontaneous dissections, however, are difficult to compare directly owing to differences in how these lesions occur; the mechanism of injury can affect progression or healing. Moreover, spontaneous dissections are often discovered and reported in the medical literature owing to symptoms such as headache, neck pain, cerebral ischemia, cranial nerve palsies, or oculosympathetic palsy at presentation; only a minority of spontaneous dissections are discovered in asymptomatic individuals.[21] Screening imaging is used for the trauma patient, and symptoms attributable to dissection may be absent or difficult to clearly discern acutely in this setting.

TREATMENT

Medical

Commonly accepted first-line treatment regimen in the setting of carotid arterial dissection at most trauma centers includes the administration of antithrombotic medications when possible to prevent thromboembolic complications of dissection and/or dissecting aneurysm. No randomized prospective studies have defined optimal medical treatment of cervical arterial dissection, and there are no prospective comparative studies between medications and control.[22,23] Lyrer et al.[24] performed comprehensive searches in 2010 and found no difference in outcomes when comparing anticoagulants to antiplatelet agents across 36 observational studies. However, the authors found neither completed randomized trials comparing either anticoagulants or antiplatelet drugs with control nor any randomized trials that directly compared anticoagulants with antiplatelet drugs. Administration of these medications, especially anticoagulants, may not always be feasible in the setting of a traumatic carotid injury because these patients may have comorbid contraindications to blood thinning medications. Endovascular stent repair generally requires the use of antiplatelet medications before and after stent placement to prevent platelet aggregation on the stent and the use of intraprocedural anticoagulants to help prevent thromboemboli related to catheters and other intraluminal devices. Both aspirin and clopidogrel are generally used before and after stenting, continuing Clopidogrel for several months after the procedure and aspirin for life.

Endovascular and Surgical

Endovascular repair of these lesions has gained more widespread acceptance as the preferred treatment modality in comparison with traditional surgical techniques. Carotid injuries from blunt trauma are often located near the skull base, an area particularly hazardous to approach and difficult to repair surgically. Extensive exposures necessary to achieve adequate proximal and distal vessel control may result in significant cranial nerve damage. If the injured vessel is inaccessible, proximal occlusion or segmental isolation

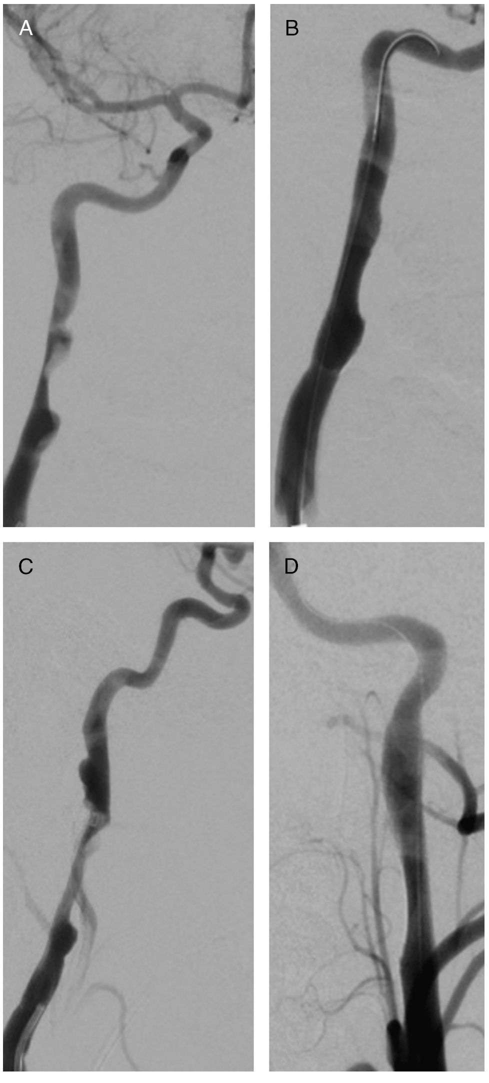

Figure 3. A 24-year-old patient after a motor vehicle collision presented with bilateral cervical ICA injuries and head CT evidence of small bilateral multifocal infarctions (not shown). *A*, Left anterior oblique projection DSA image of the right ICA on posttrauma Day 4 demonstrates traumatic cervical ICA dissection–related narrowing, associated dissecting aneurysm, and probable intraluminal thrombus. *B*, Left anterior oblique DSA of the right ICA immediately after stent reconstruction demonstrates patency of the ICA with some residual aneurysmal irregularity of the midcervical ICA. *C*, Lateral projection DSA image of the left ICA demonstrates traumatic cervical left ICA dissection–related narrowing and associated dissecting aneurysms. *D*, Anteroposterior DSA image of the left ICA immediately after stent reconstruction demonstrates patency of the ICA with mild residual vessel irregularity of the midcervical left ICA. The patient continues to recover from infarctions experienced before stent repair and has minor neurologic deficits 1 month after procedure. Vessel remodeling may continue to occur on further follow-up imaging (not shown).

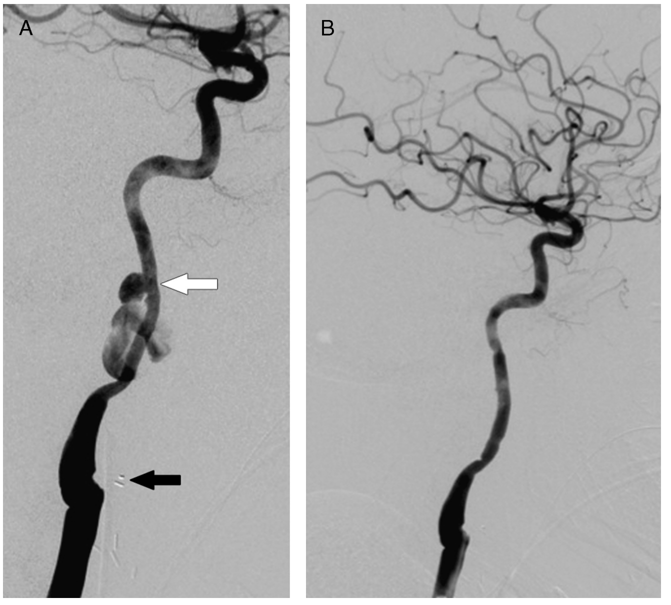

Figure 4. A 51-year-old female status post–stab wound to the neck. *A*, Left common carotid injection digital subtraction angiogram demonstrates focal extravasation of contrast material from the midcervical left ICA (white arrow). Surgical clips from left external carotid artery sacrifice are present (black arrow). *B*, Post–covered stent graft repair left common carotid artery injection demonstrates no residual contrast material extravasation from the left ICA and no evidence of flow limitation within the left ICA.

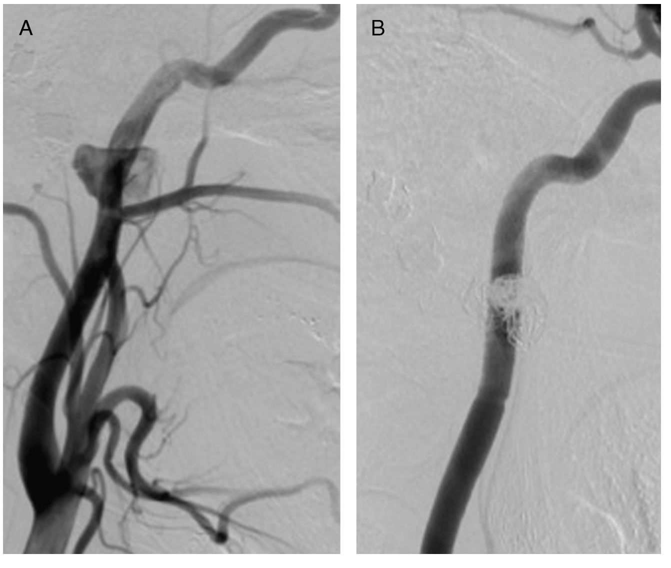

Figure 5. A 22-year-old male status post–gunshot wound to the neck presents with ipsilateral Horner's syndrome. Lateral projection DSA image of the CCA demonstrates a traumatic dissecting aneurysm of the distal cervical ICA (*A*). Six-month follow-up posttreatment lateral projection DSA image upon contrast material injection of the ICA demonstrates stent-assisted coiling of the aneurysm without residual filling of the aneurysm and minimal vessel irregularity at the proximal tines of the stent (*B*). The patient was symptom free at follow-up.

are options. Reconstruction with an in situ vein graft or extracranial-to-intracranial bypass may be technically feasible but carries significant risk of morbidity. In the largest reported series of patients with carotid dissection treated surgically, Müller et al.[25] reported a stroke rate of 10%, and cranial nerve injury in 58% of 48 patients. Ten patients experienced early postoperative vein graft occlusion.[25] In the setting of acute cerebral ischemia, temporal and logistical considerations are additional factors that may make surgical repair a less feasible immediate option.

Indications for Endovascular Repair

Indications for endovascular management of traumatic ICA dissections generally include hemodynamic compromise to the brain (Fig. 1), acute and/or delayed ischemic brain lesions (Figs. 2 and 3), persistence or worsening of the lesion on follow-up imaging (Fig. 4), contraindications to anticoagulation such as intracranial dissection or hemorrhage, and dissecting aneurysm rupture (Fig. 5), although these indications have not been individually reviewed by a body of experts. Unrepaired dissecting aneurysms carry a risk of thromboembolic sequela, rupture, Horner's syndrome, and cranial neuropathy (Fig. 5). These lesions classically fail to resolve with anticoagulation alone.[17,26] Current practice is to treat patients with stenosis and/or dissecting aneurysm who have lesions that appear unlikely to resolve with conservative measures such as severe stenoses or free floating thrombus, patients who are symptomatic despite medical therapy, and/or those patients who have significant worsening of lesions on follow-up angiography. Asymptomatic patients and those with relatively benign appearing lesions are usually counseled, and these patients may choose in collaboration with their physicians to be treated with stent repair. Most choose to not repair all small dissecting aneurysms immediately but instead often obtain short-interval follow-up imaging and pursue endovascular repair if the lesion worsens during this interval. This was the indication for treatment in the majority of traumatic dissecting aneurysms of the cervical ICA treated with stent repair in the currently largest series on the topic described by Seth et al.[27]

Safety and Feasibility of Endovascular Repair

Endovascular stent reconstruction of cervical arterial dissection has been shown to be safe and technically feasible in the short term. A review of the literature by Pham et al.[28] recently described a 99% to 100% success rate with minimal complications or bad outcomes. Mean clinical follow-up was approximately 18 months, and neurologic events were seen in 1.4% of patients. Stent graft patency in a meta-analysis of extracranial carotid aneurysms in 224 patients from 1995 to 2010 was 93% at a mean follow-up of 15 months.[29] Multiple previous small case series have shown high initial technical success rates, low complications rates, and high rates of continued vessel patency on follow-up imaging.[30–32] While the results from these relatively small case series are encouraging, many of these reports address outcomes after stenting of spontaneous cervical arterial dissection rather than traumatic carotid arterial dissection.

Most previous studies specifically focused on the endovascular repair of traumatic ICA lesions are also limited to case reports and retrospective case series, many of which are small case series. The use of uncovered stents for treating traumatic dissecting aneurysms was first reported in the late 1990s with good anecdotal success.[33–35] DuBose et al.[36] conducted a review of the medical literature and found that endovascular stenting for the treatment of traumatic ICA injuries was reported for 113 patients from 1994 to 2007. In that analysis, initial endovascular stent placement was successful in 76% of patients, follow-up ranging from 2 weeks to 2 years revealed stent patency of 79%, and new neurologic deficits after stent placement occurred in 3.5%.

TABLE 1. Summary of Current Literature on Stent Repair of Cervical ICA Dissection

Authors and Year	Journal	Manuscript Type	n	Etiology	Devices	Stent Patency	M/M*
Seth et al.,[27] 2012	*AJNR Am J Neuroradiol*	Retrospective series	50	Traumatic	Stent (88%) Majority bare metal Stent/coils (8%) Coils (4%)	98%	0%
Li et al.,[29] 2011	*Eur J Vasc Endovasc Surg*	Meta-analysis	224	Traumatic (51%) Other causes (49%)	Stent Bare metal (68%) Stent graft (32%)	93%	6%
Pham et al.,[28] 2011	*Neurosurgery*	Literature review	153	Traumatic (48%) Spontaneous (37%) Iatrogenic (16%)	Stent Majority bare metal Minority stent grafts	99–100%	1.4%
DuBose et al.,[36] 2008	*J Trauma*	Literature review	113	Traumatic (100%)	Stent Mix of bare metal and stent graft	79%	3.5%
Kadkhodayan et al.,[39] 2005	*AJNR Am J Neuroradiol*	Retrospective series	27	Traumatic (35%) Spontaneous (31%) Iatrogenic (35%)	Angioplasty/stent	91%	8%
Cothren et al.,[37] 2005	*Arch Surg*	Prospective series	23	Traumatic (100%)	Stent bare metal (near 100%)	55%	17%
Bush et al.,[32] 2001	*J Endovasc Ther*	Retrospective series	5	Traumatic (60%) Iatrogenic (40%)	Stent/coils (100%) Bare metal (100%)	100%	0%
Bejjani et al.,[31] 1999	*Neurosurgery*	Retrospective series	5	Traumatic (60%) Spontaneous (20%) Iatrogenic (20%)	Stent (100%) Bare metal (100%)	100%	0%
Liu et al.,[30] 1999	*Neurosurgery*	Retrospective series	7	Traumatic (28%) Spontaneous (42%) Iatrogenic (28%)	Stent (76%) Bare metal (100%) Stent/coils (14%) Bare metal (100%)	86%	0%

*Morbidity and mortality.

The largest published single series to date specifically addressing endovascular treatment of traumatic internal carotid arterial injuries was recently described by Seth et al.[27] In that series, 47 patients underwent stent treatment of 50 traumatic ICA injuries, 44 of which were with stents alone. Half of the treated vessels resulted in complete restoration of normal vessel lumen diameter, and the other half had good-to-acceptable initial restoration. A single patient had complete stent occlusion; there was no mortality or permanent morbidity from carotid artery repair, although long-term follow-up was not provided. The second largest single studies on endovascular treatment of traumatic carotid injuries were by Cothren et al.[37] in 2005 and Cohen et al.[38] in 2012. Cothren et al. described outcomes of 23 patients with persistent traumatic carotid artery dissecting aneurysms and demonstrated 4 complications in 23 patients undergoing carotid stent placement, that is, 3 strokes and 1 subclavian artery dissection. Follow-up angiography performed in 18 patients from that series demonstrated that eight patients had poststent carotid occlusion. Carotid occlusion rates were significantly different in patients with stents (45%) versus those who received antithrombotic agents alone (5%). It should be noted that no patients in the stent group studied by Cothren et al. received antiplatelet medications. In comparison, Cohen et al. also reported treatment of 23 traumatic carotid dissections and saw no procedure-related complications, no neurologic sequelae, and no in-stent narrowing or thrombosis at approximately 29-month mean clinical follow-up.[38] Results from the study of Cothren et al. are significantly less favorable with regard to stent repair of these lesions in comparison with the results of the report by Seth et al.[27,37] Patients undergoing stent repair in the group of Seth et al. all received antiplatelet medications before and after stent placement, suggesting the importance of these medications in the maintenance of stent patency. Moreover, the operators in the study of Seth et al. were subspecialized head and neck endovascular operators, while those in the study of Cothren et al. were not.

In 2005, Kadkhodayan et al.[39] reported results from 26 subjects treated with balloon angioplasty and stent repair but included patients with traumatic, spontaneous, or iatrogenic dissections. This study demonstrated that dissection-induced stenosis resolved in 20 of 21 patients with measurable stenosis without procedural strokes. Two patients in this series had occlusion of the treated vessel at follow-up, although neither of these two patients had been on a clopidogrel regimen. Balloon angioplasty was not performed in any of the cases reported from the study of Seth et al.;[27] rather, a second stent was placed in that series when it was felt that the first stent was not adequate in reestablishing vessel patency.

The results from these studies are summarized in Table 1.

Endovascular Devices

The use of a stent alone for treatment of these injuries emphasizes that coil deployment into an associated dissecting aneurysm, while adding an additional element to the case may not always be required to achieve a satisfactory result immediately and/or at follow-up. Stent deployment adheres intimal flaps to the vessel wall and promotes laminar flow through the lumen, diverting flow away from the dissecting aneurysm, and stent endothelialization occurs over weeks to months. The introduction of crush-resistant nickel titanium (nitanol) has improved conformability, strength, and durability of these devices.

Covered stents may be considered in the setting of arterial extravasation. A disadvantage of covered stent grafts is their lack of mechanical flexibility.[40] Furthermore, results of stent graft patency in the carotid artery have demonstrated relatively higher rates of in-stent narrowing and occlusion compared with those of Seth et al.[27] An analysis of 20 patients who received covered stent grafts for the treatment of traumatic ICA dissecting aneurysms showed a 15% rate of occlusion at follow-up.[41] Other smaller case series on stent grafting of traumatic carotid lesions have shown mixed results at follow-up.[42–46]

Intentional endovascular occlusion of the ICA is a treatment option in those patients with adequate collateral blood flow via the Circle of Willis. However, even after successfully passing a balloon occlusion test, patients who undergo endovascular occlusion of the ICA may experience postprocedural stroke. A literature review performed by Mathis et al.[47] revealed that ICA sacrifice after clinical passage of a balloon occlusion test alone resulted in 9 permanent strokes (4.7%) in 192 patients. The mortality rate was 0.

LIMITATIONS

Several unique limitations should be considered when pursuing endovascular repair of the carotid arteries. Local access site complications have been shown to occur in 3% of elective cases in the treatment of cerebrovascular disease.[48] Anatomic difficulties may preclude safe access to the injured vessel. No device is currently Food and Drug Administration approved for this indication, and long-term limitations of available stent types remain largely unknown. There is a lack of consensus with regard to indications for endovascular repair, follow-up antithrombotic regimen, and ideal type or interval for subsequent follow-up. Optimal radiologic follow-up has not been agreed upon. Duplex ultrasound may miss subtle stenoses or dissecting aneurysms, especially near the skull base. As CT technology continues to evolve, this may be the noninvasive study of choice, although conventional catheter-based angiography remains the criterion standard in this setting. Stent-and/or coil-related artifacts can interfere with optimal evaluation of a vessel on CT, and magnetic resonance angiography is susceptible to artifacts from these devices as well. Despite these uncertainties, endovascular stent repair after carotid trauma has shown early promise in its safety and efficacy profiles. Furthermore, as both acceptance of carotid arterial stent repair and operator experience continue to evolve, results may continue to improve in the coming years. Further investigation is warranted, and long-term data with late follow-up results will be necessary to provide a better understanding of the safety and efficacy of these devices.

CONCLUSION

Endovascular stent repair for the treatment of traumatic ICA dissecting aneurysms is a safe and technically feasible treatment option in the short term, although its long-term efficacy remains unproven. Stent repair alone without coils and the use of a single-bare metal stents without coils can be used to sufficiently exclude a dissecting aneurysm from the parent artery while maintaining patency of the parent artery. The results in the current medical literature are encouraging, but long-term data with late follow-up results will be necessary to provide a better understanding of the safety and efficacy of stents used for carotid artery injuries.

AUTHORSHIP

G.J. contributed in the literature review, data collection, writing of the manuscript, writing of the table, as well as obtaining and editing of the images. M.F. contributed in the editing of the images, manuscript, and references. T.M. contributed in the editing of the images, manuscript, and references. T.S. contributed in the editing of the manuscript and references. D.G. contributed in the editing manuscript and provided oversight.

DISCLOSURE

The authors declare no conflicts of interest.

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