ASK THE EXPERTS

Reducing Stroke Risk During TEVAR in the Arch

Although single- and double-branch stent grafts have been promising, they may also increase the risk of stroke. Panelists offer their thoughts on options to help reduce risk of stroke in arch procedures.

With Brant W. Ullery, MD, MBA, FACS, FSVS; William Hiesinger, MD; Toru Kuratani, MD; Sonia Ronchey, MD; and Tim Resch, MD, PhD

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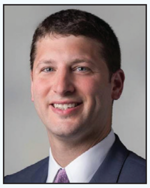

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The next wave of complex thoracic endovascular aortic repair (TEVAR) is a welcomed addition to the armamentarium of cardiac and vascular surgeons who treat aortic arch pathologies. As we have long recognized across the aortic spectrum in the 30 years of endovascular aortic therapies, there is always an Achilles' heel to such interventions. In the thoracic space, neurologic complications (eg, stroke, spinal cord ischemia) infuse an appropriate humility to the otherwise favorable clinical outcomes in such patients compared to conventional open aortic arch reconstructions. Aortic arch pathologies invite a host of unique variables to TEVAR (eg, dynamic motion, extreme aortic arch angulation, atheromatous disease of the supra-aortic arch vessels, hemodynamic derangements) that subject these procedures to additional technical challenges and a growing predisposition to neurologic complications. Such risks are further amplified in current clinical practice that is void of standardized techniques and commercially available branch devices for the arch, as well as marked by a diversity of aortic pathologies and acuities unlike any other aortic segment.

We believe that optimal endovascular and hybrid management of aortic arch pathologies relative to neuroprotection begins with detailed preoperative case planning. Dedicated imaging with gated CTA is helpful to reduce artifacts related to prior aortic interventions and cardiopulmonary motion, as well as to note precise locations of dissection flaps, ulcerations, and the interface between an open interposition bypass and native aorta. Three-dimensional centerline reconstructions are imperative to guide the overall strategy of the case as they relate to employment of techniques involving feasibility of branched devices (currently confined to clinical trial settings), extra-anatomic bypass/debranching, in situ laser fenestration, physician-modification endografting, and/or parallel stent graft technologies. Identification of significant atheromatous debris, hostile iliofemoral access, aortic tortuosity, and lack of appropriate proximal seal zone characteristics may favor consideration of antegrade access for TEVAR deployment with or without cardiopulmonary bypass.

Regardless of chosen technique, tedious attention to fundamentals of TEVAR, including thorough flushing of the device during preparation, careful and intentional wire manipulation in the arch, maintenance of appropriate intraoperative anticoagulation (eg, activated clotting time [ACT] > 250-300 seconds), and consistent awareness of goal blood pressures (eg, transient hypotension during deployment of proximal device, followed by immediate restoration of normotension or permissive hypertension dependent on extent of aortic coverage) are imperative.

Some have advocated for flushing devices with carbon dioxide or in an underwater bath before insertion to further decrease the potential for air embolus.[1] Others have suggested a low threshold for utilization of embolic protection devices to minimize the risk for these same embolization events.[2]

Cases involving excessive atheromatous disease of the arch commonly prompt us to consider a technique (eg, in situ laser fenestration or chimney) that affords the opportunity for carotid clamping (and subsequent flushing) as a more definitive method of embolic protection. Alternatively, supra-aortic arch vessels with significant ostial occlusive disease may be bypassed all together (extra-anatomic) with subsequent ligation of the proximal portion of the vessel prior to TEVAR to eliminate the athero/thromboembolic potential in that arterial bed. Permissive hypertension is instituted during any carotid clamping to minimize the risk of stroke due to concomitant cerebral hypoperfusion. Additionally, when able, our groups routinely revascularize the left subclavian artery (LSA), as we believe the net benefit of optimizing the posterior cerebral circulation as it relates to decreasing risk of both stroke and spinal cord ischemia exceeds the potential interval increase in stroke risk related to this adjunctive procedure alone.

1. Kölbel T, Rohlffs F, Wipper S, et al. Carbon dioxide flushing technique to prevent cerebral arterial air embolism and stroke during TEVAR. J Endovasc Ther. 2016;23:393-395. doi:10.1177/1526602816633705
2. Shah AS, Akhmerov A, Gupta N, et al. Use of a dual-filter cerebral embolic protection device in thoracic endovascular aortic repair. Ann Vasc Surg. 2020;65:54.e1-54.e4. doi:10.1016/j.avsg.2020.01.077

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We have performed TEVAR using three types of branch devices for aortic arch pathology in 35 patients. Although we do not discuss device-specific stroke rates at this time, we found that 13% of all patients had strokes (including those diagnosed on MRI).

At our institution, we use thin-slice multidetector CT to evaluate the intravascular thrombus in detail before surgery. We prioritize debranching TEVAR in the presence of even a small thrombus in the cervical branch vessels and ascending aorta. In high-risk patients with a small amount of thrombus, we must use a filter in the cervical branch to perform branched TEVAR. Even with this strategy, about 13% of postoperative strokes occur due to branched TEVAR, raising the question of whether the current filter device is functioning effectively. Based on these results, it must be said that using the available branch device options, it is difficult to prevent cerebral infarction. However, it is worth considering the indications for TEVAR in cases where conventional surgical techniques, including debranching TEVAR, are not feasible. It is similar to the positioning of transcatheter aortic valve implantation (TAVI) at the beginning of its introduction. In addition, branched TEVAR is an excellent indication for residual dissection. In our experience, devices other than the Gore TAG Thoracic Branch Endoprosthesis can be used, and we have not seen any cerebral infarction in patients with enlarged false lumen after ascending aortic replacement.

We would like to strongly assert that the use of branch devices with well-restricted indications in the future will directly lead to the prevention of cerebral infarction and improvement in the results of branched TEVAR.

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Branch stent grafts appear to be an attractive solution to reduce mortality and morbidity in older/fragile patients or in patients with previous ascending or hemiarch replacement or previous sternotomy. The risk of stroke is probably the major drawback of these procedures; it increases from zone 2 to zone 0, where the rate is up to 30% is some series. Recent studies with diffusion MRI show the presence of new silent brain infarct in 50% of patients.

Stroke in such complex procedures is of multifactorial origin: embolism of thrombotic or atherosclerotic material during arch maneuver, inadvertent coverage of an anomalous left vertebral artery originating directly from the arch, coverage of a LSA in presence of a dominant left vertebral artery, an air bubble released during the deployment of the graft, and/or the use of cardiac pacing.

Several strategies are used to prevent stroke during the procedures:

- Accurate preoperative planning is fundamental to identify anatomic anomalies and the presence of thrombus and atheroma; anticipating these challenges (ie, use of through-and-through wire, stiff buddy wire) can minimize manipulations and difficulties at advancing devices, reducing stroke risk.
- Surgical revascularization of a left vertebral artery originating from the arch and carotid subclavian bypass.
- Arch maneuvers in any case must be gentle; using a catheter to exchange soft with stiff wires, the stiff wire must remain in stable position during the procedure. If snaring of a wire is necessary, it should be performed in the distal arch or descending aorta.
- Adequate heparinization is fundamental; ACT time must be > 250 seconds.
- In case of previous carotid-to-subclavian bypass, the embolization of the LSA origin before stent grafting seems to reduce the risk of stroke.
- Adequate deairing of the stent graft is fundamental; usually a 0.9% heparinized solution is used to remove air from the stent graft. Some studies demonstrate that deairing with high-volume saline solution (> 120 mL) can be useful to reduce the risk of neurologic complications. Another adjunct is represented by a second flushing of the graft in the descending thoracic aorta so that eventual microbubbles are carried distally.
- Another option is to flush the graft for 2 minutes with carbon dioxide before a standard saline flush.
- The choice of the graft can be important in case of a shaggy aorta to reduce stroke risk. The possibility to use grafts that are inserted on a soft through-and-through wire that are released starting from a side branch without further catheterization could potentially reduce the risk of stroke; similarly, when feasible (eg, saccular aneurysm of the inner curve), a fenestrated configuration with a graft that can be released without cardiac pacing can represent a good option to reduce stroke risk.
- Moreover, the recent broad experience with TAVI suggests that the use of an embolic protection device represents a good tool to reduce stroke risk. At the moment, many of the available arch embolic protection systems cannot be used in arch procedures for different reasons, and the true advantage of their use is not clear but certainly must be evaluated. Application-specific protection devices will likely become available in the near future.

All the techniques I have mentioned are useful to keep the occurrence of neurologic events during endovascular arch repair as low as possible, but they do not eliminate the risk.

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Surgical repair of the aortic arch remains a challenging procedure. The gold standard of total arch repair, including the frozen elephant trunk technique, is well established but is still fraught with a non-negligible risk of stroke, particularly in reoperative cases. This has led to the search of a better, minimally invasive endovascular approach but also to an increased interest in the underlying causes of perioperative stroke during aortic arch repair. Recent studies with diffusion-weighted MRA have, for instance, shown a high subclinical stroke risk after regular TEVAR and also that many endovascular TEVAR delivery systems in fact contain trapped air that might escape and possibly embolize during TEVAR delivery.

Endovascular arch repair requires the same rigorous process as other complex aortic endovascular repairs to minimize the risk of complications in all stages of treatment: planning, operative technique, and postoperative management.

Patient selection is critical for success. An aortic arch with large amounts of atheroma (eg, shaggy aorta) should be avoided if possible. Although the scientific evidence is low, clinical experience strongly supports this, and reports from endovascular thoracoabdominal aortic aneurysm repair strongly indicate that shaggy aortas are a risk factor. Furthermore, published series on endovascular arch repair indicate significantly less stroke in dissection versus aneurysm patients, and the latter clearly have more atheroma in the arch. Other factors such as tortuous or atherosclerotic supracervical trunks (used for branch access) or adverse arch configuration (type I vs III) should also raise warning flags.

During the operation, general rules apply. Minimal arch manipulation by using fusion overlay techniques as well as adequate levels of anticoagulation is important. We routinely aim for ACT levels > 300 seconds. Due to the risk of air trapping in the endovascular device, we routinely flush the device with carbon dioxide for 2 minutes and complete with aggressive heparin saline flushing. Like others, we currently use a retrograde approach to the target vessels and surgically expose the carotid arteries to be able to clamp during deployment and flush after delivery.

The techniques described have lowered the stroke risk but have not eliminated it. However, endovascular total arch repair is still under development and new techniques and devices require new technical adaptations. Triple branch devices and total femoral approaches are being used selectively, driving the procedure toward a complete percutaneous approach. With this, certain embolic prevention steps, such as clamping of cervical trunks, are removed and might need to be replaced with others such as filters or flow reversal. The appropriate postoperative anticoagulation regimen is still not defined and needs to be better studied.

Patient selection, detailed planning, intraoperative technique and guidance, and optimal device preparation remain critical to avoid preventable strokes during endovascular arch repair. ■