

Strategies for Stroke Prevention During TEVAR: From Embolic Protection to Device Preparation and Delivery

Technologic developments and techniques for lowering the risk of cerebral injury and stroke after TEVAR.

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Over the last few decades, thoracic endovascular aortic repair (TEVAR) has become the treatment of choice for different aortic pathologies, because it is considered a lower-risk treatment with a minimally invasive approach.¹ Evidence suggests that TEVAR may offer at least early benefit in terms of mortality and morbidity as compared with open repair.^{2,3} However, the Achilles heel of this procedure remains the incidence of neurologic events, and stroke has become an increasingly recognized complication after TEVAR. A recent meta-analysis including 2,594 patients highlighted that the pooled stroke incidence may vary from 3.2% up to 8% in patients undergoing TEVAR.⁴ This clinical stroke rate does not include the more frequently detected silent ischemic infarction (SII), which occurs in approximately 80% of patients after TEVAR and represents neuronal cell death, thereby leading to permanent brain damage. Recent neuroimaging studies showed that more than half of patients undergoing TEVAR have new SII on MRI.^{5,6} Transcranial Doppler can detect cerebral emboli and alterations in blood flow patterns, which may show which steps of TEVAR are most likely to provoke hemodynamic changes and embolic events.⁷

Recent European Society for Vascular Surgery guidelines recommend revascularization of the left subclavian artery as the only preventive measure for stroke during TEVAR in cases where its coverage is planned (class IIa, level of evidence C).¹ However, the main source of embolic material during TEVAR is the manipulation of guidewires, catheters, and endografts within the aortic arch, which has the potential to mobilize debris. Assessment of aortic atheroma may be helpful during preoperative planning for TEVAR. Gutsche et al suggested a classification for

aortic atheroma according to the thickness and presence of protruding atheroma: grade I is defined as a smooth and continuous aortic intimal surface, grade II as intimal thickening of 3 to 5 mm, grade III as atheroma protruding < 5 mm into the aortic lumen, and grade IV as atheroma protruding > 5 mm into the aortic lumen and ulcerated or pedunculated.⁸

TECHNOLOGIC DEVELOPMENTS: ROBOTICS AND EMBOLIC PROTECTION DEVICES

The recent technologic developments in robotics may offer new instruments to improve clinical outcomes. A recent report highlighted that robotic catheter placement during TEVAR may result in significantly less cerebral embolization compared with manual techniques. The active maneuverability, control, and stability of the robotic system make contact with an atheromatous aortic arch wall less likely and thereby dislodgement of particulate matter is reduced, resulting in less embolization.⁹

Studies have also suggested that the use of filters as embolic protection similar to other vascular procedures, such as carotid stenting and transcatheter aortic valve replacement (TAVR), could also be an adjunct maneuver for preventing stroke during TEVAR.¹⁰ A recent study presented the outcomes of three different filter devices: Parachute (Tri-Med), a nitinol basket filter with pores of 0 to 450 μm ; Filtrap (Nipro), a self-expanding, nitinol, spiral-based device consisting of a polyurethane filter with a 100- μm pore size and is available in four different device diameters from 3.5 to 8 mm; and FilterWire EZ (Boston Scientific Corporation), which is composed of a nitinol filter loop and polyurethane filter bag with a 110- μm pore size and is available in diameters ranging from 3.5 to

5.5 mm. The authors suggested that filter protection could be an adjunct maneuver for preventing critical stroke during endovascular arch repair.

The Sentinel cerebral protection system (CPS) (Boston Scientific Corporation) has recently been assessed for use in TEVAR.¹¹ The Sentinel CPS, which has been widely used in TAVR, is a 6-F, 100-cm-long, steerable sheath comprising two conical filters made of a 140- μ m-pore biocompatible polyurethane film. Access is achieved either through the right radial or brachial artery under fluoroscopic guidance. The proximal part of the system is first deployed at the origin of the brachiocephalic trunk, and the distal part is deployed into the left common carotid artery. In this pilot study of 10 patients who underwent TEVAR, the use of the Sentinel CPS appeared to be safe and feasible, but further study is needed.

Ischemic brain injury related to embolization has been thoroughly studied in patients undergoing TAVR; thus, new strategies have been developed to protect the brain from embolic debris and these strategies might be useful if applied during TEVAR.^{12,13} The TriGuard 3 embolic deflection device (Venus Medtech Inc.) is designed to provide three-vessel protection in most anatomies, with less interference with TAVR devices. The Point-Guard dynamic cerebral embolic protection (Transverse Medical, Inc.) is a complete cerebral embolic protection device (EPD) with maximum coverage of all great arch vessels. ProtEmbo CPS (Protembis GmbH) is also designed to protect all supra-aortic vessels by deflecting potentially embolic debris downstream. The low-profile design should allow relatively easy delivery by radial access and it is the only available protection device for TAVR using left radial artery access. The Emblok EPS (Innovative Cardiovascular Solutions LLC) provides complete protection for the cerebral, as well as abdominal and peripheral, vasculature during valve implantation and other left-sided heart procedures. The Embrella embolic deflector (Edwards Lifesciences) works by deflecting the emboli with a dual membrane system positioned along the greater curvature of the aorta covering the ostia of the first two large branches. These EPDs may be an alternative for embolic protection in TEVAR; however, clinical studies will assess their use.

CARBON DIOXIDE FLUSHING TECHNIQUE

In a recent study, Grover et al investigated the utility of a filter CPS to reduce SII caused by solid embolization during TEVAR.¹¹ Interesting findings were that the majority of high-intensity transient signals (HITSs) were gaseous (91%), not solid, and that the maximum number of HITSs occurred during stent deployment. This study amplified that the general hypothesis for the main origin of stroke may not be atherosclerotic particles during wire and device manipulations but instead other sources such as

air embolus during the procedure. The significant amount of air bubbles released by TEVAR devices may account for the protective value of flushing the delivery systems for TEVAR with carbon dioxide. This technique was introduced in 2014 and has gained widespread acceptance as a safe and effective method to reduce air embolization in TEVAR.¹⁴ The higher solubility of carbon dioxide in blood compared with room air may reduce the damage caused by embolizing gas bubbles.

Makaloski et al studied the distribution of air bubbles in the supra-aortic vessel in an aortic flow model during thoracic stent graft deployment, suggesting that a significant number of air bubbles are released during deployment of tubular thoracic stent grafts distally of the left subclavian artery.¹⁵ Along this line, Rohlfes et al investigated the amount of gas released from Zenith thoracic stent grafts (Cook Medical) using a standard saline flushing technique versus the carbon dioxide flushing technique in the experimental bench setting.¹⁶ Ten grafts were flushed with 60 mL of 0.9% saline and another 10 grafts were flushed with carbon dioxide from a cylinder for 5 minutes, then 60 mL of 0.9% saline. Thoracic endografts released significant amounts of air during deployment, even if flushed according to the instructions for use, and the application of carbon dioxide to flush thoracic stent grafts prior to standard saline flush significantly reduced the amount of gas released during deployment.

Recently, another study demonstrated that the amount of gas released from thoracic stent grafts during deployment can be influenced by different flushing techniques.¹⁷ In particular, the use of liquid perfluorocarbon in addition to the carbon dioxide flushing technique reduced the volume of gas released to a few microliters during the deployment of tubular thoracic stent grafts. In addition to these new flushing techniques, it was demonstrated that reducing the air-filled space inside the pusher of the catheter assembly using an additional side port can further reduce the amount of air released.¹⁸ Thus, combining the use of the extra side port along with the carbon dioxide flushing technique (and potentially liquid perfluorocarbon) may reduce gas release further to small volumes.

CONCLUSION

The use of embolic protection filters in cases of severe aortic atheromatosis and the flushing techniques in all cases could potentially lower the risk of cerebral injury and stroke during TEVAR. ■

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