Interventional neuroradiology is not just interventional radiology in the brain. The vessels are smaller, more delicate, and the consequences of mistakes are deadly. The smaller, softer, and safer principle applies to all procedures and equipment. Each year, advances in imaging and equipment technology occur. Like all endovascular procedures, basic principles apply. Each case begins with a complete review of the patient’s history and all previous imaging. The importance of good fluoroscopy equipment and appropriately trained staff cannot be overstated. The list of available catheters, wires, and other devices is extensive and constantly changing. In this article, we briefly review some of the common procedures and equipment available to interventional neuroradiologists. What we discuss is by no means comprehensive or complete in terms of procedures performed or equipment available.

**CEREBRAL ANGIOGRAPHY**

Obtain an iliac and femoral angiogram through the sheath once it is inserted. This way femoral artery injury is immediately detected. An exchange to a long sheath may negate the effects of tortuous or diseased vessels. Cerebral angiography should include images of the aortic arch, at least two views of the carotid bifurcations, intracranial circulation via injections of each carotid artery, and the origins of the vertebral arteries and posterior circulation. It is important to understand brain perfusion. Seeing what artery is supplying a particular territory, if communicating arteries are patent, and what collaterals are present is crucial. Generally, selective internal carotid artery (ICA) injections are not necessary, unless you are looking for an aneurysm or other vascular malformation. First, ensure there is no contraindication to entering the ICA by means of biplane angiography. Do not enter the ICA if there is plaque or excessive tortuosity that may predispose to distal emboli or dissection. Vertebral arteries are delicate, and even the softest catheter can easily cause dissection. Diagnostic angiograms of the posterior circulation are easily achieved with the catheter in the subclavian artery.

Figure 1. Stent-assisted cerebral aneurysm coiling with a Neuroform stent (Boston Scientific Corporation, Natick, MA).
Core Knowledge for Cerebral Angiograms
- Double-flush and meniscus-to-meniscus technique
- Flush catheters regularly
- Tip of syringe must point down, do not inject anything pink or resembling soda
- Do not jab the vertebral artery with a wire or the tip of the catheter

Sheaths
- 5-F short sheath
- 5-F long sheath (to navigate the effects of tortuosity or stenosis in the iliac vessels)

Catheters
- 5-F pigtail (to access aortic arch anatomy)
- 5-F JB-1 (Cook Incorporated, Bloomington, IN) is the selective catheter of choice for cerebral angiography and is soft and safe.
- 5-F Sim 2 (Cook Incorporated) is ideal for the left carotid of a bovine arch.
- 4-F Sim 1 (Cook Incorporated) nonglide is ideal for challenging anatomy, atraumatic to form.

Diagnostic Guidewires
- .035-inch hydrophilic wire (the guidewire of choice for cerebral angiography).
- .038-inch hydrophilic wire (tortuous anatomy)
- .035-inch shapable hydrophilic wire (a wide curve can send you in the right direction)

Interventional Sheaths
- 6-F short sheath
- 6-F long sheath
- 6-F Shuttle sheath (tip placed in common carotid, enhances access and minimizes device exchanges)
- 5-F Vitek and 6-F Shuttle sheath (Cook Incorporated) (the Vitek used instead of Cook’s Slip-Cath is ideal for difficult anatomy)

Interventional Guidewires
- Transend, .014-inch to .010-inch (Boston Scientific Corporation)
- Agility, .010-inch, .014-inch, .016-inch (Cordis Endovascular, Warren, NJ)
- Mirage, .008-inch (ev3, Inc., Plymouth, MN)

CAROTID STENTS
It is important to review previous imaging before starting the procedure. Control angiography of the brain before and after the procedure is essential. Microembolization during carotid stenting is very commonly documented by transcranial Doppler during the procedure and by postprocedural diffusion-weighted imaging. Absence of the anterior and middle cerebral artery branches due to macroembolism can be subtle. Comparison of the baseline cerebral angiogram to the final angiogram is particularly crucial for non-neuroradiologists.

Acculink
The Acculink (Abbott Vascular, Santa Clara, CA) is a self-expanding nitinol stent. A tapered stent allows placement across the carotid bifurcation. This is used in combination with the Accunet cerebral protection device, which is a micromesh filter basket on the end of the delivery catheter.

INTRACRANIAL STENTS
Wingspan
Atherosclerotic intracranial arterial stenosis is a high-risk disease and a common cause of stroke. Both high-dose aspirin and warfarin have been shown to be ineffective in this setting. The Wingspan (Boston Scientific) is the only FDA-approved stent for intracranial atherosclerotic disease refractory to medical treatment. It is a highly flexible, self-expanding, nitinol stent. The stenosis is angioplastied to 80% of the stent size with the Gateway PTA balloon system (Boston Scientific) prior to stent deployment. This submaximal balloon dilatation may reduce the incidence of perforating branch occlusion and in-stent restenosis.

COVERED STENTS
iCast
The iCast (Atrium Medical Corporation, Hudson, NH) is a balloon-expandable, PTFE-covered stent that is ideal for securing the carotid in acute trauma or from tumor infiltration. Eventually, most small-caliber covered stents thrombose despite antiplatelet treatment. Even though it is tightly crimped with an ultralow crossing profile, crossing any stenosis using a balloon-mounted stent is not without the risk of early deployment.

STENT-ASSISTED ANEURYSM COILING
Neuroform
The Neuroform (Figure 1) is a flexible, self-expanding, microcatheter-delivered, nitinol stent. It is used for the treatment of wide-neck cerebral aneurysms that may not otherwise be amenable to endovascular therapy. It provides parent vessel protection during coil embolization of cerebral aneurysms.

RETRIEVAL DEVICES
The Attracter
The Attracter Endovascular Snare (Boston Scientific) consists of fiber strands that are attached to the distal tip of a core wire. The fibers, when manipulated, work to ensnare a misplaced coil.
Alligator
The Alligator Retrieval Device (Chestnut Medical, Menlo Park, CA) is a retriever with grasping jaws and is attached to the tip of a flexible wire. The jaws are closed by advancing a microcatheter forward. The whole device is then withdrawn through the guiding catheter.

Amplatz Gooseneck Snares and Microsnares
These devices (ev3) have a single 90°-loop configuration for coil retrieval and manipulation.

MICROCATHETERS
There are many microcatheters available; the goal is atraumatic access. They vary in stiffness, tractability, and inner- and outer-diameter luminal size. Ideally, a catheter that will push and track but remain stable is desired. Catheter braiding increases axial rigidity and improves stability. Many catheters have a proximal braided staff with a softer, more flexible distal end. An appropriately sized microcatheter is selected for each procedure by considering catheter flexibility, stability, guiding catheter, and devices to be inserted into the microcatheter. The journey traveled by the microcatheter, the length, morphology, and tortuosity of the anatomy must also be considered.

Core Knowledge for Microcatheters
- Make sure everything fits (sizes of wires, coils, etc.) and dry table test, if necessary
- Start slowly and gently
- Chose optimal obliquity
- Always remove the sack from the system
- If something is not advancing, understand why, do not just push harder

Excelsior SL-10
The Excelsior SL-10 (Boston Scientific) is a steam-shapeable microcatheter with an unbraided tip that is soft and flexible. Its .0165-inch inner lumen will accommodate a .014-inch microwire.

Renegade 18
The Renegade 18 (Boston Scientific) is a braided, steam-shapeable microcatheter that has greater axial strength for negotiating challenging anatomy. The .021-inch inner lumen will accommodate all GDC coils.

Echlon 10 and 14
The Echlon 10 and 14 (ev3) are preshaped over-the-wire microcatheters and are available in a variety of tip configurations.

Prowler
The Prowler microcatheter family (Prowler 10, 14, Prowler-Plus, and Prowler Select [Cordis Neurovascular, Miami Lakes, FL]), has a proximal braided shaft with a distal platinum tip, giving a variety of inner- and outer-lumen diameters. The hub is made of nylon with a PTFE inner coating.

EMBOLIZATION
Therapeutic embolization is a well-established tool for the treatment of many head and neck vascular lesions. Multiple embolic agents are available including polyvinyl alcohol (PVA), sodium tetradecyl, ethanol, embospheres, and glue.

PVA
PVA has traditionally been the gold standard embolic particle because it is both biocompatible and efficient as a permanent embolic agent. However, as it is hydrophobic and irregular in shape, particles tend to cluster and create aggregates of an unpredictable size.

Tris-Acryl Gelatin Microspheres
These are small spheres of a plastic called polycrylamide and gelatin. They are hydrophilic, biocompatible, nonresorbable, and uniformly spherical. These calibrated microspheres are easy to deliver through a microcatheter, quickly and reliably reducing blood flow. The size of the occluded vessel correlates well with the size of the embospheres. They have better sizing and penetration characteristics than PVA, but deaths have been reported from progressive irreversible hypoxemia.
especially with smaller microspheres (40-120 µm). They are ideal for maxillary artery embolization in the setting of epitaxis, glomus tumor embolization, and head and neck cancers (500-700 µm is usually ideal) (Figure 2).

**Liquid Embolic System**

This liquid glue system is made up of n-butyl cyanoacrylate, ethiodized oil, and tantalum powder. Under fluoroscopic guidance, it is used to obstruct or reduce the blood flow to cerebral arteriovenous malformations via superselective catheter delivery. The mixture polymerizes into a solid material upon contact with blood or tissue. Higher concentrations of ethiodized oil increase the polymerization time, which allows better distal penetration of the nidus of the arteriovenous malformations. High concentrations of n-butyl cyanoacrylate result in a faster polymerization rate allowing proximal embolization. Tantalum powder is added to increase radiopacity.

**Thrombolysis**

Stroke is a leading cause of mortality and morbidity in the developed world. We now have the concept of salvageable brain tissue. Both intravenous and intra-arterial thrombolysis have been proven effective in the acute treatment of embolic stroke. In addition, endovascular mechanical embolectomy has been shown to be an effective means of revascularization. The Merci (mechanical embolism removal in cerebral ischemia) Concentric Retriever (Concentric Medical, Mountain View, CA) is a device that consists of a microcatheter and wire. The wire, when advanced, forms a corkscrew shape distal to a clot, which is then withdrawn back into the proximally positioned microcatheter. Currently, few patients are candidates for intravenous thrombolysis alone. Combining protocols of intravenous thrombolysis, intra-arterial thrombolysis, and mechanical thrombectomy will help to improve patient outcomes.

**CONCLUSION**

Interventional neuroradiology is a minimally invasive, exciting, and expanding endovascular specialty. A wider range of complex vascular disorders of the brain, spine, head, and neck are now treatable with new endovascular technology. Wide-neck cerebral aneurysms are now amenable to endovascular coiling due to balloon remodeling or stent-assisted embolization. Further growth is seen in areas such as intra-arterial chemoembolization and acute stroke treatment.

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