Neurointervention for the Peripheral Radiologist: Tips and Tricks

**Rush Chewning, B.A.,¹ Gerald Wyse, M.D., M.R.C.P.I.,¹
and Kieran Murphy, M.D., F.R.C.P.C., F.S.I.R.¹**

ABSTRACT

Interventional neuroradiology is a high-risk, high-yield field with small margins for catastrophic errors. A wider range of complex vascular disorders of the brain, spine, head, and neck are now treatable with new endovascular technology. This article describes new tools and techniques in this ever-expanding field.

KEYWORDS: Neurointervention, catheter, embolization, angioplasty

IMPORTANT BASIC PRINCIPLES

Interventional neuroradiology is a high-risk, high-yield field where the patient has an average stroke risk of 5 to 8% and mortality risk of 1 to 2% in very experienced hands.¹ Risks escalate with interventions above the skull base. These thin-walled vessels are small and delicate, and their location in the subarachnoid space complicates the situation further. They float freely in cerebrospinal fluid, unsupported by bone or muscle, making them susceptible to tearing. Mistakes here are deadly. Although extracranial vessels are more robust, they are still friable and susceptible to rupture or dissection. A sense of the acceptable forces (the good and bad resistance) grows with experience.

ANTICOAGULATION

Anticoagulation using heparin is vital. We heparinize all of our diagnostic cerebral angiogram patients with 2000 IU except for those with acute subarachnoid hemorrhage. We heparinize all interventional patients with a 5000-IU bolus once arterial access is achieved with a 6F sheath. The only exception to this rule is in patients with acute subarachnoid hemorrhage requiring embolization. In these patients, we delay the heparin bolus until the

first coil is placed in the aneurysm. We even heparinize patients with epistaxis.² Additionally, counter to surgical practices, we do not stop other forms of antiplatelet therapy, such as Plavix or aspirin, in patients who require it. We believe this practice reduces platelet aggregation on catheters and other devices, thereby reducing procedural stroke risk.

The use of heparin in all flushes (4000 IU in 1 L of normal saline) is critical even in patients already on heparin. This is particularly true when using guiding catheters. Most procedural strokes occur due to clot formation in guiding catheters resulting from failure to flush, flushing too infrequently, or using nonheparinized flushes.³ Additionally, keeping gloves clean using heparinized saline can also prevent the transfer of clots from gloves to guidewires or catheters.

SEDATION AND ANESTHESIA

We recognize there is debate concerning whether conscious sedation is necessary in all cases. However, it is our belief that all patients should receive light conscious sedation at a minimum. To do otherwise is cruel. These procedures can be painful and unnerving for patients, and ensuring patient comfort is of utmost importance.

¹Division of Interventional Neuroradiology, Department of Radiology, Johns Hopkins University, Baltimore, Maryland.

Address for correspondence and reprint requests: Kieran Murphy, M.D., F.R.C.P.C., F.S.I.R., Division of Interventional Neuroradiology, Department of Radiology, Johns Hopkins Hospital, 600 N. Wolfe Street, Baltimore, MD 21287 (e-mail: kmurphy@jhmi.edu).

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This is simply good practice and treating people well, but it also has practical benefits. A comfortable patient moves less, allowing for the use of roadmap guidance.

Good coordination with anesthesia, when indicated, should be ensured. We use general anesthesia in all cases anticipated to last > 1 hour, when the procedure is anticipated to be particularly painful, or when patients are unable to tolerate or cooperate with the procedure—typically elderly or young patients, or patients with cognitive limitations. At times other factors, such as the need for intraprocedural functional testing, preclude anesthesia use. Decisions about the use of anesthesia are thus made on a case-by-case basis.

ANATOMY

A critical source of potential complications involves anatomy. The famous “dangerous anastomoses” between the extracranial and intracranial circulations serve as shunts through which embolic material can cause strokes.⁴ These anastomoses occur around the orbit, the cavernous sinus, and the foramen magnum. Strokes can be avoided by performing microcatheter diagnostic angiography prior to any injection of embolic material and by using larger embolic material.⁵ Never use embolic particles < 200 microns—particles of this size can get anywhere! (There is really no reason to use them anyway.) Of particular concern is the potential for spinal cord infarct when using small particles in spine interventions.⁶ This point is relevant for bronchial embolization also.

EQUIPMENT, PERSONNEL, AND MINIMIZING DISTRACTIONS

The importance of good fluoroscopy equipment and appropriately trained staff cannot be overstated. If you need something in a hurry, you don’t want a technician or nurse who does not know what it is or where it is kept. Minimizing distractions such as these will help keep your focus. A dedicated team is crucial to provide the highest level of care. Thinking ahead to other potential intraprocedural distractions or delays is also important. For example, consider insertion of a bladder catheter before lengthy procedures, particularly in elderly patients. The last thing you want to do is lose time putting a patient on a bedpan while you have a microcatheter in his or her extracranial circulation.

HISTORY AND PHYSICAL EXAMINATION

Each case begins with a complete review of the patient’s history and all previous imaging, as well as an analysis of risks and benefits at least the day before the procedure. It is best to have performed a patient consult a week before the procedure. Disposition of the patient must be planned before you begin. A preprocedure note with a

history and physical examination of a neurologist’s standard needs to be written. Terms like “PEARRL” and “cranial nerves I-XII” are not good enough. Do the examination, document it, and understand it before you begin. This will save your hide if anything goes wrong. If there is any doubt, get a head computed tomography before the procedure. Document, document, document!

CEREBRAL ANGIOGRAPHY

Perform an iliac and femoral angiogram through the sheath once it is inserted. This ensures that any iatrogenic injury caused by access is detected immediately. (Since we introduced this policy two years ago, we have not had a single femoral dissection in almost 1000 cases.) An exchange to a long sheath may negate the effects of tortuous or diseased vessels. Table 1 lists diagnostic sheaths that are commonly used in cerebral angiography. A cerebral angiogram 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. The 30 mL of contrast spent in doing an arch injection will save you the 40 mL you will use later while trying to navigate through a difficult arch with the wrong diagnostic catheter.

Understanding brain perfusion is crucial: which artery is supplying a particular territory, whether communicating arteries are patent, and if collaterals are present. Generally, selective internal carotid artery (ICA) injections are not necessary unless you are looking for an aneurysm or other vascular malformation. First, ensure in two planes that there is no contraindication to entering the ICA with a catheter. Do not enter the ICA if there is plaque or excessive tortuosity that may predispose to distal emboli or dissection. Vertebral arteries are quite 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. Tables 2 and 3 list the commonly used catheters and guidewires used to perform a cerebral angiogram.

Always double-flush and use meniscus-to-meniscus technique. Bubbles are your enemy! Flush catheters regularly. If you can’t hold your breath that long, it’s time to flush. Never inject anything that looks like club soda or is pink! This isn’t the liver. You can’t get away with it in the head. Never straighten a vessel with a wire or the

Table 1 Diagnostic Sheaths

Sheath Type	Comments
5F short	
5F long	Negates effects of tortuosity or stenosis in iliac vessels
4F	Used in children

Table 2 Catheters

Catheter Type	Ideal Use	Notes
5F pigtail	To access aortic arch anatomy	
5F JB-1 glide (Cook, Bloomington, IN)	Selective catheter of choice for cerebral angiography	Soft and safe
5F Simmonds 2 nonglide (Cook)	Great for left carotid of bovine arch	
4F Simmonds 1 nonglide (Cook)	For challenging anatomy	Atraumatic to form

tip of the catheter. These vessels probably haven't been straight since childhood.

DEVICES AND TECHNIQUES

The "smaller, softer, and safer principle" applies to all procedures and equipment. Every year sees advances in imaging and equipment technology. As with all endovascular procedures, you must resist the temptation to get lost in the technology and forget fundamental principles. Diagnostic angiography is performed first, usually via femoral access. There is a dogma that wires dissect vessels. People, not wires, dissect vessels! Table 4 lists the guiding catheters and sheaths used to perform interventional neurovascular procedures.

Carotid Stents

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 procedure⁷ and by diffusion-weighted imaging after the procedure.⁸ Absence of anterior and middle cerebral artery (MCA) branches due to microembolism can be subtle. It is usually the anterior division of the MCA that is affected. This is difficult vessel for thrombolysis, and it is too small to attempt clot retrieval.⁹ (It will rupture. Remember stroke is better than death.) Again, comparison of the baseline cerebral angiogram with the final angiogram is crucial for all procedures. Open-cell stents are more flexible than closed-cell stents. Thus, they provide better apposition to the vessel wall and are thereby less likely to cause vessel straightening, which is associated with restenosis at the proximal and distal ends of the stent. Some investigators believe that open cell stents are associated with a higher risk of embolization, however.

Table 3 Diagnostic Guidewires

Wire Type	Comments
0.035 glide	Guidewire of choice for cerebral angiography
0.038 glide	Great for tortuous anatomy
0.035 shapeable glide	A wide curve can send you in the right direction

Table 5 lists both uncovered and covered stents used in the treatment of carotid disease.

Intracranial Stents

WINGSPAN

Atherosclerotic intracranial arterial stenosis is a high-risk disease and a common cause of stroke. Both high-dose aspirin and warfarin are ineffective in this setting. Wingspan (Boston Scientific, Natick, MA) is the only stent approved by the Food and Drug Administration (FDA) for intracranial atherosclerotic disease refractory to medical treatment. It is a highly flexible self-expanding nitinol stent. The stenosis is dilated to 80% of the stent size with the Gateway PTA Balloon Catheter (Boston Scientific, Natick, MA) prior to stent deployment. This submaximal balloon dilation may reduce the incidence of perforating branch occlusion and stent restenosis. The FDA granted the Wingspan a humanitarian device exemption, and it can only be used in patients on Medicaid if they are in a study. It requires institutional review board or western institutional review board approval (Figs. 1 and 2).

Stent-Assisted Aneurysm Coiling

NEUROFORM

Neuroform (Boston Scientific, Natick MA) is a flexible self-expanding, microcatheter-delivered nitinol stent. It is used for the treatment of wide-necked cerebral aneurysm that may not otherwise be amenable to endovascular therapy. It provides parent vessel protection during coil

Table 4 Interventional Guiding Catheters and Sheaths

Type	Comments
Envoy MPC (Cordis, Miami Lakes, FL)	The workhorses of interventional neuroradiology; available in 5F and 6F
Shuttle sheath	Tip placed in carotid for maximum stability; enhances access and minimizes device exchanges
Vitek (Cook, Bloomington, IN)	Used instead of Slip-Cath (Cook); 6.5F used with shuttle sheath for tortuous anatomy

Table 5 Carotid Stents

Stent Type	Design	Comments
Acculink (Guidant, Temecula, CA)	Open cell, self-expanding nitinol	Use with Accunet (Guidant)*
Xact (Abbott, Redwood City, CA)	Open cell, self-expanding nitinol	Use with Emboshield (Abbott)*
iCast (Atrium, Hudson, NH)	Covered, balloon-expandable PTFE	Use in trauma, tumor infiltration†

*Both the Acculink and Xact stents are used in conjunction with cerebral protection devices, which are micromesh filter baskets on the end of the delivery catheter.

†This covered stent is ideal for securing the carotid in acute trauma or in cases of tumor infiltration. It is tightly crimped with an ultraslow crossing profile. However, crossing any stenosis using a balloon-mounted stent is not without the risk of early deployment. We use this device for carotid blowouts in head and neck cancer patients and for our gunshot wound and stab wound patients. It is very effective, although sometimes we have to put in multiple stents. Eventually most small-caliber covered stents thrombose despite antiplatelet treatment (i.e., clopidogrel and aspirin for 3 months, followed by aspirin for a lifetime).

embolization of cerebral aneurysms. Either Wingspan or Neuroform stents can be used in a similar manner to treat wide-necked renal aneurysms (Fig. 3).

Figure 1 Digital subtraction angiogram showing a tight basilar artery stenosis.

Figure 2 Digital subtraction angiogram postangioplasty and stenting with a Wingspan stent (Boston Scientific, Natick, MA).

Retrieval Devices

THE ATTRACTER ENDOVASCULAR SNARE

Fiber strands are attached to the distal tip of a core wire in the Attractor Endovascular Snare (Boston Scientific, Natick, MA). The fibers, when manipulated, work to ensnare a misplaced coil.

ALLIGATOR RETRIEVAL DEVICE

The Alligator Retrieval Device (Chestnut Medical, Menlo Park, CA) has grasping jaws attached to the tip of a flexible wire. Advancing a microcatheter forward closes the jaws, and then the whole is withdrawn through the guiding catheter.

AMPLATZ GOOSENECK SNARES AND MICROSNARES

The Amplatz snares and microsnares (EV3, Plymouth, MN) have a single 90-degree loop configuration for coil retrieval and manipulation.

Microcatheters and Wires

Many microcatheters are available. The goal is atraumatic access. They vary in stiffness, tractability, and inner and outer diameter luminal size. Ideally you want a catheter that will push and track yet remain stable.

Figure 3 Stent-assisted aneurysm coiling with a Neuroform stent (Boston Scientific, Natick, MA).

Table 6 Microcatheters and Wires

Microcatheter Type	Characteristics	Notes
Excelsior SL-10 (Boston Scientific, Natick, MA)	Steam shapeable; unbraided tip that is soft and flexible; inner lumen 0.0165 accommodates 0.014 wire	
Renegade 18 (Boston Scientific, Natick, MA)	Braided, steam shapeable; 0.021 inner lumen accommodates all GDC coils	Great axial strength for challenging anatomy; very lubricious
Echelon 10, 14 (EV3, Plymouth, MN)	Preshaped; available in a variety of tip configurations	
Prowler 10, 14, plus and select (Cordis, Miami Lakes, FL)	Proximal braided shaft with distal platinum tip; available in a variety of inner and outer lumen diameters	Nylon hub with PTFE inner coating

GDC, Guglielmi detachable coil; PTFE, polytetrafluoroethylene.

Catheter braiding increases axial rigidity and improves stability. Many catheters have a proximal braided shaft with a softer more flexible distal end. An appropriate-size 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, including the length, morphology, and tortuosity of the anatomy, must be also considered. The technique of steaming a microcatheter is very useful because the shape that conforms to a vessel will give the catheter stability during the procedure. Table 6 lists microcatheters and microwires used commonly at our institution. For our interventional guidewires we use the Transend 10/14 wires (Boston Scientific, Natick, MA) almost exclusively; however, we also use the Agility 10/14/16 (Cordis, Miami Lakes, FL) and the Mirage 0.08 (EV3, Plymouth, MN).

Before beginning a procedure, ensure that all equipment sizes are compatible with one another and that everything fits (sizes of wires, coil, etc.). Perform a dry table test if necessary or if using unfamiliar equipment. Choose optimal obliquity. Always remove the slack from the system. Begin slowly and proceed gently. If something is not advancing, understand why. Do not simply push harder!

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 sulfate, ethanol, Embospheres (BioSphere Medical, Rockland, MA), and glue.

POLYVINYL ALCOHOL

Polyvinyl alcohol has traditionally been the gold standard embolic particle because it is both biocompatible and efficient as a permanent embolic agent. However, because it is hydrophobic and irregular in shape, particles

tend to cluster and create aggregates of an unpredictable size.

TRISACRYL GELATIN MICROSPHERES (EMBOSPHERES)

Embospheres are small spheres composed of a plastic called trisacryl gelatin. They are hydrophilic, biocompatible, nonresorbable, and uniformly spherical. These calibrated microspheres are easy to deliver through a microcatheter, and they reduce blood flow quickly and reliably. The size of 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 to 120 μm) (Fig. 4).

TRUFILL LIQUID EMBOLIC SYSTEM (CORDIS)

This liquid glue system is made up of n-butyl cyanoacrylate (n-BCA), ethiodized oil, and tantalum powder. It is used under fluoroscopic guidance to obstruct or reduce the blood flow to cerebral arteriovenous malformations (AVMs) via superselective catheter delivery. The mixture polymerizes into a solid material on contact with

Figure 4 Embospheres in a branch of the facial artery during embolization of bleeding neck carcinoma.

blood or tissue. Higher concentrations of ethiodized oil increase the polymerization time, which allows better distal penetration of the nidus of the AVM. High concentrations of n-BCA result in a faster polymerization rate, allowing proximal embolization. Tantalum powder is added to increase radiopacity and lower viscosity.

ONYX LIQUID EMBOLIC SYSTEM

Onyx is another option for embolizing an AVM. However, we do not use onyx because injections take a great deal of time and are extremely painful to patients. Additionally, onyx is flammable under bipolar cautery when an AVM is resected in the operating room. Finally, the dimethyl sulfoxide in this product can cause patients to smell strongly of garlic for days to weeks.

Thrombolysis

Stroke is a leading cause of mortality and morbidity in the developed world. The concept of salvageable brain tissue now exists. Both intravenous and intra-arterial thrombolysis have been proven effective in the acute treatment of embolic stroke. In addition, endovascular mechanical embolectomy is an effective means of revascularization. The Merci (mechanical embolism removal in cerebral ischemia) Concentric Retriever (Concentric Medical, Mountain View, CA) 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. (Our experience has been that this retriever has only worked in 1 of 10 cases.) 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.

FINAL THOUGHTS

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-necked cerebral aneurysms are now amenable to endovascular coiling, owing to balloon remodeling or stent-assisted embolization.¹⁰ Further growth can be seen in areas like intra-arterial chemoembolization and acute stroke treatment.

As important as the devices are, the most critical piece of the puzzle is your work environment. Effort put into building networks of support repay enormously, particularly when procedures go poorly.

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