Basic Neuroangiography: Review of Technique and Perioperative Patient Care

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Abstract

Neuroangiography (NA) is an important part of diagnosis and treatment of patients with neurological disease. Although NA may be performed for diagnostic purposes, in many instances NA is performed with the intent to treat. Indications for NA range from extracranial diseases (vertebrobasilar insufficiency from subclavian steal, extracranial carotid stenosis, cavernous-carotid fistula, neck trauma, epistaxis, tumor invasion of the carotid artery, and tumor embolization) to intracranial diseases (nontraumatic subarachnoid hemorrhage, cerebral aneurysms, cerebral arteriovenous malformations, cerebral vasospasm, acute stroke, tumor embolization, and WADA test). Similar to peripheral angiography, appropriate preprocedural assessment and postprocedural care, along with understanding of anatomy, catheter technique, and disease processes, are vital to successful outcomes. This article will review the basic technique, equipment, and patient management in NA. With appropriate skill and knowledge, interventional radiologists can perform NA with safe and successful results.

Keywords

- ► neuroangiography
- ► technique
- ► arteriography
- ► interventional radiology

Objectives: Upon completion of this article, the reader will be able to describe basic neuroangiography including indications, technique, complications, and patient care.

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Diagnostic neuroangiography (NA) and many neurointerventions are clearly within the skill set of most interventional radiologists, assuming one is willing to develop a thorough understanding of the intra- and extracranial anatomy and particular catheter skills required for this type of work. This article will review the basic techniques, equipment, and perioperative patient management in NA. Although some of this will be familiar and intuitive due to the similarities and translation of catheter skills between peripheral body angiography (PA) and NA, other techniques may be new or different from those routinely used for PA.

Indications

NA may be performed for diagnostic and interventional purposes. Advances in noninvasive vascular imaging have supplanted many traditional applications for routine diagnostic NA. This is best exemplified by the standard use of duplex ultrasound, computed tomographic angiography (CTA), and magnetic resonance angiography for evaluation and grading of extracranial internal carotid artery (ICA) stenosis. NA is generally reserved for situations in which noninvasive imaging may be inconclusive or when two studies are contradictory. In contradistinction, nontraumatic subarachnoid hemorrhage work-up requires NA, as it remains as the gold standard, especially for the detection of cerebral aneurysms. At the

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author's institution, nontraumatic subarachnoid hemorrhage patients are typically imaged with noncontrast head CT, followed by NA. Although CTA may be performed as a problem-solving tool in a small number of cases, there is little evidence to suggest that routine use in this setting adds any benefit; NA has the advantage of providing both diagnostic information (aneurysm, arteriovenous malformation (AVM), etc.) and allowing treatment in cases where pathology is present.

NA may be performed for extracranial and intracranial pathology as outlined in ►**Table 1**. Extracranial diseases include vertebrobasilar insufficiency from subclavian steal, extracranial carotid stenosis, cavernous-carotid fistula, neck trauma, epistaxis, tumor invasion of the carotid artery, and tumor embolization. The most common intracranial diseases evaluated with NA include nontraumatic subarachnoid hemorrhage, cerebral aneurysms, cerebral arteriovenous malformations, cerebral vasospasm, acute stroke, tumor embolization, and WADA test (►**Fig. 1**).

Patient Preparation

Preprocedure

Before proceeding to any procedure or treatment, the interventional radiologist (IR) should perform a consultation, which includes a focused history and physical exam, and a review of available imaging and laboratory values. The IR should be facile with basic neurological assessment. Working knowledge of National Institute of Health Stroke Scale is advised for those involved in acute stroke care and interventions. Appropriate communication with the relevant referring physician(s) is recommended. If NA is deemed appropriate, detailed informed consent should be obtained including specific risks of the procedure. Laboratory parameters may include complete blood cell count, serum creatinine or glomerular filtration rate, and protime/international normalized ratio, as dictated by the patients' clinical situation. Anticoagulants should be held when possible. Patients should eat nothing by mouth 6 hours before the procedure. The morning insulin dose should be reduced in half. Inguinal regions and/or the left arm should be sterilely prepared as dictated by the particular case. A neurological assessment should be performed and documented immediately before the procedure before sedation or anesthesia.

Table 1 Common indications for neuroangiography

Extracranial	Intracranial
Extracranial carotid stenosis	Acute stroke
Carotid blowout	Nontraumatic subarachnoid hemorrhage
Subclavian steal	Nontraumatic parenchymal cerebral hemorrhage
Cervical trauma	Intracranial aneurysm
Epistaxis	Cerebral vasospasm
Preoperative tumor embolization	Intracranial arteriovenous malformations
	Preoperative tumor embolization
	WADA test

Contraindications

There are no absolute contraindications to NA. Relative contraindications include contrast allergy, renal insufficiency, and coagulopathy. In the presence of severe contrast allergy, alternatives to iodinated contrast agent should be considered; otherwise, standard prophylaxis is recommended.[1] The authors prefer 32 mg of methylprednisolone, 12 and 2 hours before the procedure. If nondialysis-dependent renal insufficiency is present, judicious use of iodinated contrast is recommended. The authors prefer pre- and postprocedure hydration with normal saline as the data for *N*-acetylcysteine and bicarbonate infusion are equivocal at best.[2] Coagulopathy should be corrected when possible.

Sedation and Patient Positioning

Sedation and analgesia with intravenous midazolam and fentanyl is appropriate for most diagnostic NA. Presedation evaluation should include American Society of Anesthesia and airway assessments. For more complex neurointerventions, such as cerebral aneurysm coil embolization, general anesthesia may be required.

Patients should be positioned supine with a headrest. Patients who are unable to cooperate may need to have their head gently taped to reduce motion. To reduce motion artifact, patients should be warned of potential sensation of heat with each injection and to avoid swallowing when imaging the neck vasculature.

Diagnostic Cerebral Angiography Technique

Access

The authors prefer the right common femoral artery (CFA) for access, similar to PA. When CFA access is not optimal, brachial artery access may be required. Direct common carotid artery (CCA) access is mainly of historic interest but may be required in emergent situations. Unsuccessful arterial access attempts should be minimized especially if anticoagulation or thrombolytic usage is anticipated. Some operators prefer use of small bore access needles, for example, micropuncture systems or ultrasound guidance. The authors tend to use standard 18 G access needles unless the pulse cannot be reliably palpated. Once successful access is gained, a 5-F sheath may be placed and set to a continuous heparinized saline infusion. If brachial artery access is required, meticulous attention should be paid for hemostasis.

Catheterization

There are a wide range of available catheters, wires, and sheaths for NA. When choosing a catheter, one should consider the patient's age, vascular anatomy (review of any prior studies or prior cross-sectional imaging is helpful), injection rates, and compatibility of sizes and lengths. Cervical arch aortogram (CAA) may be useful when: (1) there is question of disease in the origins of the great vessels, (2) an initial

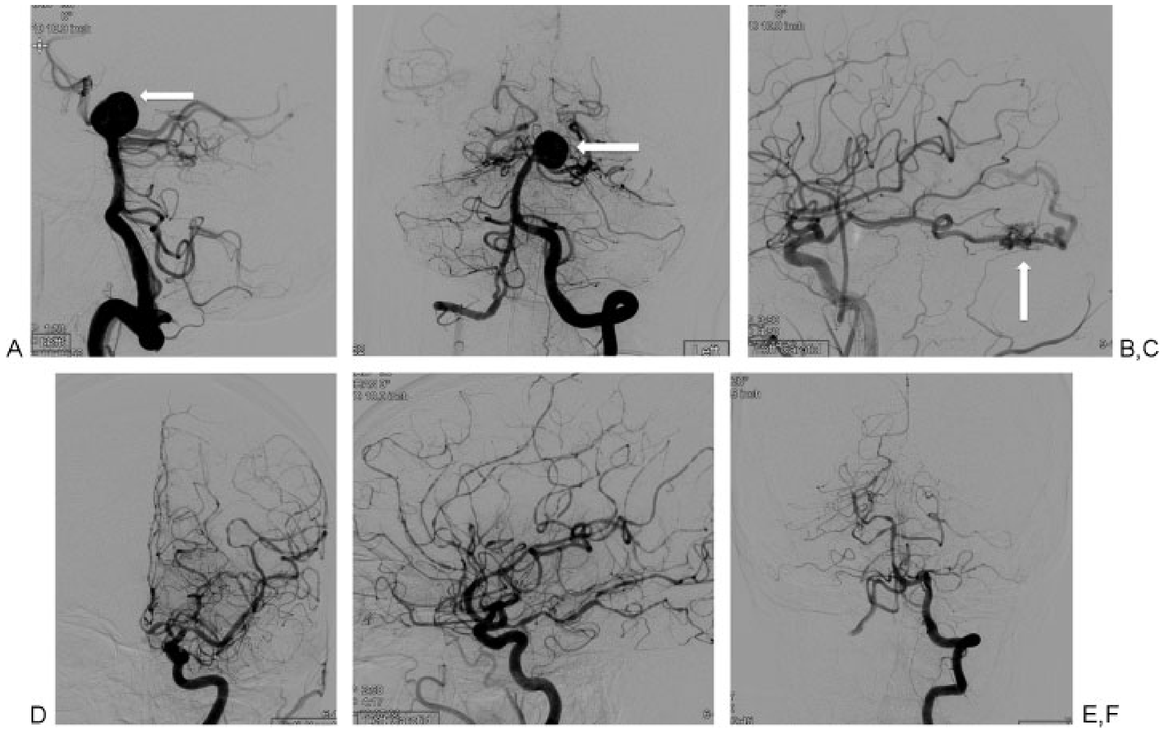

Figure 1 Examples of indications for NA. (A) Lateral and (B) AP views of a basilar tip (arrow) aneurysm. (C) Left cerebellar AVM (arrow), best imaged on lateral projection from a left carotid selective injection. AVM fills via fetal origin of the left posterior cerebral artery (PCA). (D–F) Diffuse cerebral vasculitis of the anterior and posterior circulation. (D) AP and (E) lateral projection of left anterior circulation, and (F) AP projection of the posterior circulation demonstrates many areas of narrowing and dilatation. AP, anteroposterior; NA, neuroangiography.

reference image is preferred due to complex aortic arch anatomy, or (3) a proximal great vessel is the targeted treatment vessel. For CAA, the catheter of choice is a multi-side-holed flush catheter. A 90-cm length catheter is required to reach the aortic arch in most patients. The injection rate is typically 20 mL/s, and the duration of injection is 2 seconds for a total of 40 mL of contrast. Once CAA is obtained, the flush catheter is exchanged for a selective catheter. Meticulous air free double flush technique is recommended to minimize unintended air or clot embolus, which may lead to undesired neurological complications. Retracting the flush catheter distal (closer to the access site) to the origins of the great vessels before catheter exchange may be preferred to reduce the possibility of inadvertent embolization to the brain.

The aortic arch anatomy will help determine the selection of the catheter for great vessel(s) catheterization(s). The aortic arch has been classified according to the origin of the great vessel in reference to the curvature of the aortic arch in the cranial-caudal dimension. For illustration, please see the article entitled "Carotid Artery Stenting: Review of Technique and Update of Recent Literature" in this issue.[3] In general, as the great vessel origin migrates caudally, the degree of difficulty increases, especially for interventions that require larger sheaths. Type I and II arch configurations can be routinely catheterized with an angled catheter, while a reverse curve catheter is generally necessary to select vessels arising from Type III arches.

Anatomic landmarks and tactile feedback from the catheter should guide catheterization technique. In younger patients, a 5-F angled catheter can be advanced without a wire using minimal contrast puffs during advancement to confirm intraluminal position. The artery can be selected in an antegrade manner or the catheter can be advanced intentionally beyond the origin of the target vessel and pulled back into the origin. As the arteries become diseased or increase in tortuosity, a guidewire is often necessary. A long tapered (15 cm floppy tip) spring-coil guidewire such as Bentsen guidewire (Cook Medical Inc., Bloomington, IN) has been a traditional favorite, but the authors prefer a hydrophilic 0.035-inch wire such as Glidewire (Terumo Interventional Systems, Somerset, NJ). Once enough wire purchase is gained, the catheter is advanced under fluoroscopic monitoring. As the wire is removed, an inadvertent vacuum effect may occur if the catheter is in a small diameter artery or if the end hole is up against the wall of the artery. To prevent inadvertent air embolus (►**Fig. 2**), the authors routinely remove the guidewire slowly, keeping the catheter hub filled with heparinized saline by dripping or injecting it into the hub while the wire is withdrawn. Another option for avoiding air embolus during NA is the use of in-line air filters and closed angiographic systems, in which continuous heparinized flush is administered through the catheter continuously and contrast injection is facilitated through the use of a stopcock. When faced with a Type 3 arch, one may opt to primarily use a reverse curved catheter. The authors prefer a Simmons 2 or Simmons 3 (Cook Medical Inc.) catheters (depending on the size of the aortic arch). Although the Simmons catheter is a reverse curve catheter, once the primary angle is retracted to the origin of the selected artery,

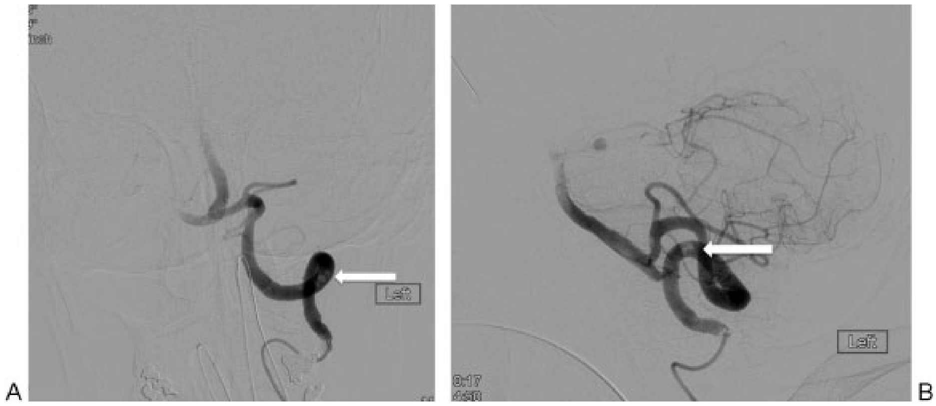

Figure 2 (A) AP and (B) lateral projections show inadvertent air embolus in the left vertebral artery (arrow). Air embolus may occur due to unanticipated vacuum effect if the catheter is in a small diameter artery or if the catheter is up against the side wall of the artery as the guidewire is removed. Guidewire removal with the hub filled with saline can help reduce this unwanted complication. Alternatively, in-line filters or closed systems can be used. AP, anteroposterior.

advancement of a guidewire (including an exchange wire) is often possible. Abrupt or rapid advancement of a stiff guidewire should be avoided as it may lead to prolapse of the catheter and wire into the proximal aortic arch. Extreme tortuosity of the great vessels, including 360-degree turns, may add additional challenges to selective catheterization. In most cases, passage of sufficient length of guidewire will straighten the vessel without issue. In some cases, however, this may lead to complete occlusion, extreme spasm of the artery, or dissection. Removal of the catheter will typically lead to resolution of vasospasm. Judgment should be exercised in extreme tortuosity. In many cases, a more proximal injection of the vessel or abortion of the procedure may be more prudent rather than forcing the catheterization and risking complications.

For routine cerebral arteriography, CCA selection is sufficient unless the external carotid branches obscure visualization of the intracranial circulation. For vertebral arterial selection, the left vertebral artery (VA) is preferred as it is more commonly larger in diameter than the right. For diminutive VA, confirmation that it does not terminate as the posterior inferior cerebellar artery (PICA) before a standard injection should be performed (►**Fig. 3**). The right VA is not routinely catheterized unless the left VA is not accessible, right VA pathology is suspected, or when contrast reflux into the right PICA is not obtained from a left VA injection. Extra care should be taken when VA selection is performed, as the VA is prone to vasospasm and dissection. Delayed or limited washout after contrast injection alerts to the possibility of vasospasm, dissection, or in rare circumstances distal embolus. In most cases, vasospasm is self-limited without any consequence once the catheter is removed. When prolonged vasospasm is present, intra-arterial delivery of nitroglycerin in 100 µg aliquots may be necessary. If a dissection is present, treatment is dictated by degree of flow limitation, contralateral VA or posterior cerebral artery collateral supply, and patient symptoms (►**Fig. 4**). Distal embolization should be managed with thrombolysis or embolectomy if deemed clinically appropriate.

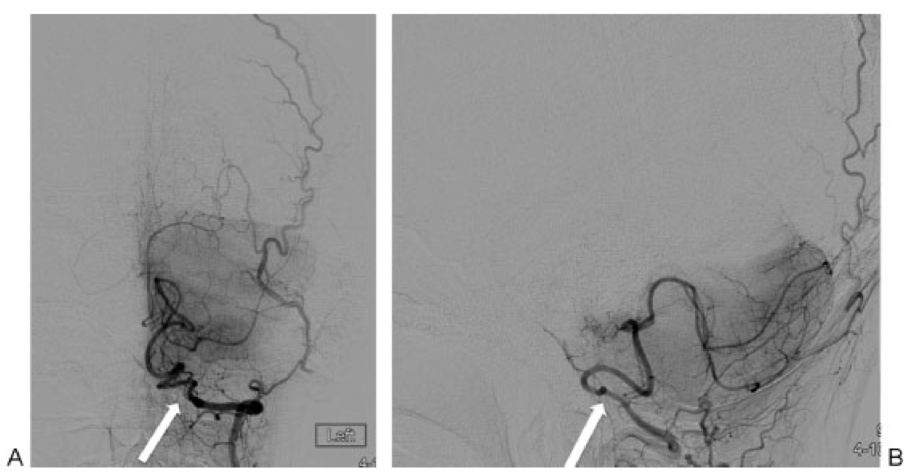

Figure 3 (A) AP and (B) lateral projections show the left vertebral artery terminating as the left PICA (arrows). Typically, such a VA is diminutive in size. A test injection should be performed to ensure that the VA does not terminate as the PICA before automated injection. AP, anteroposterior; NA, neuroangiography; PICA, posterior inferior cerebellar artery; VA, vertebral artery.

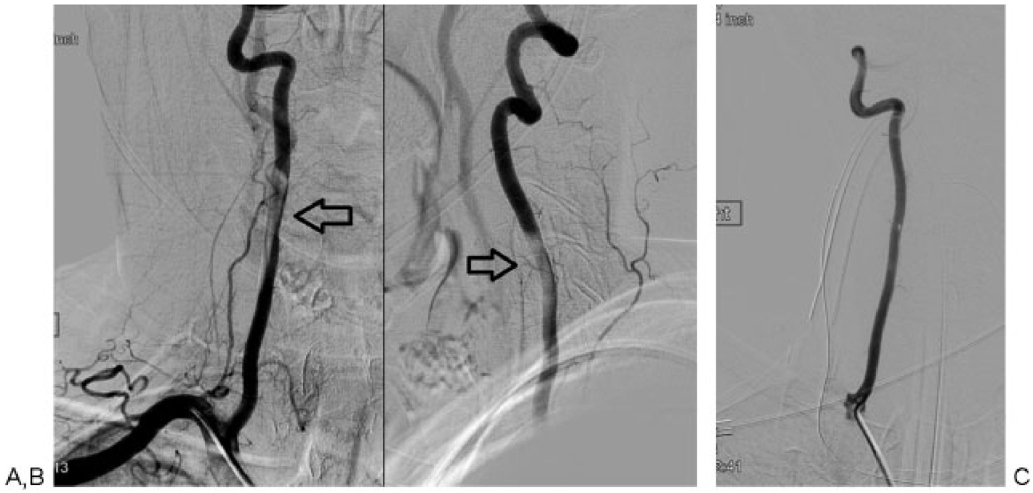

Figure 4 Vertebral artery dissection. (A) AP and (B) lateral projections demonstrate a right vertebral artery dissection (arrows) after a diagnostic NA. The presence of the dissection was noted with delayed washout of the contrast. As the imaging field typically does not include the tip of the catheter, dissections may be undetected if subtle findings are missed. Once a dissection has occurred, flow limitation, PCA collateral supply, or patient symptoms will dictate therapy. This patient was asymptomatic and was treated with 24 hours of anticoagulation followed by aspirin. (C) Repeat VA angiogram performed at the time of the patient's aneurysm treatment 1 month later showed a completely healed VA (the subtraction artifact is from an overlying device). AP, anteroposterior; NA, neuroangiography; VA, vertebral artery.

Rarely, the VA cannot be safely selected or may be nearly impossible to select. In such situations, an injection can be performed with the catheter in the subclavian artery and a blood pressure cuff inflated to an occlusive pressure on the ipsilateral arm to promote contrast flow into the VA. Although not optimal, this technique may be the only way to image the VA.

When selective ICA injection is preferred or required, an angled hockey stick-type catheter and hydrophilic guidewire are sufficient. If the arch anatomy dictates a reverse curve catheter for CCA catheterization, an exchange of catheters is required. In such cases, the initial catheter can be exchanged over an exchange length guidewire. The authors prefer to exchange the catheter with the distal wire in the external carotid artery (ECA) or the CCA if the ECA is not favorable. Placement of a long vascular sheath (e.g., 6-F Shuttle; Cook Medical Inc.) may be required for added support to avoid losing access to the selected artery. Once positioned, the sheath should be set to a continuous heparinized saline infusion. Once the sheath is secured with the distal tip in the CCA, an angled catheter or microcatheter can be used to select the desired vessel. For ECA or ICA branches, microcatheter and microwire use are recommended. For ECA branch selection, care should be made to avoid vasospasm that may limit intended therapy such as internal maxillary artery embolization for epistaxis. ECA branch selective arteriography can be performed manually or with an automated injector at a low contrast injection rate and volume. For selection of the anterior cerebral or middle cerebral arteries (MCA), a microcatheter and soft tipped microwire are recommended. In general, automated pump contrast injection or forceful manual injection is not recommended in the distal vessels, to avoid rupturing fragile perforators and to avoid contrast toxicity (especially in the setting of ischemic brain, e.g., in acute stroke interventions).[4,5] If digital subtraction imaging is required, contrast can be injected via the sheath in the CCA or the ICA (►**Fig. 5**).

C-Arm Positioning and Injection and Framing Rates

Cervical aortic arch is performed approximately 35-degree left anterior oblique position to profile the great vessel origins. The patient is positioned so that the underside of the arch is at the bottom of the imaging field. The injection rate is 20 mL/s for total of 40 mL of contrast, and the image frame rate is 3 frames per second (f/s).

For extracranial carotid arteriography, anteroposterior (AP), lateral, and 45-degree bilateral oblique projections are standard. A calibrating marker, such as 1 cm radio-opaque sphere, can be used as a reference when precise measurements are required, such as in carotid artery stenting. The injection rate is 4 to 5 mL/s for total of 7 to 9 mL, and the image frame rate is 2 to 3 f/s. Biplane capability is very helpful as it saves time, contrast, and halves the number of injections.

For anterior intracranial cerebral angiography, AP (Townes view) and lateral projections are standard (►**Fig. 6**). One helpful tip is to position the petrous bones at the level of the mid to lower orbits as a guide. Oblique images at 45 degrees may profile overlapping or redundant arteries. For evaluation of the MCA bifurcation or trifurcation, a Stenvers view is useful (►**Fig. 7**). For anterior communicating artery imaging, the submental vertex view may be required for optimal visualization. In a minority of cases, due to competitive flow, compression of the contralateral CCA is required to image the anterior communicating artery. When cross compression is performed, a radiation shield should be used to minimize radiation exposure to the operator. Newer NA suites are equipped with three-dimensional (3D) rotational capability. Available commercial software programs are capable of

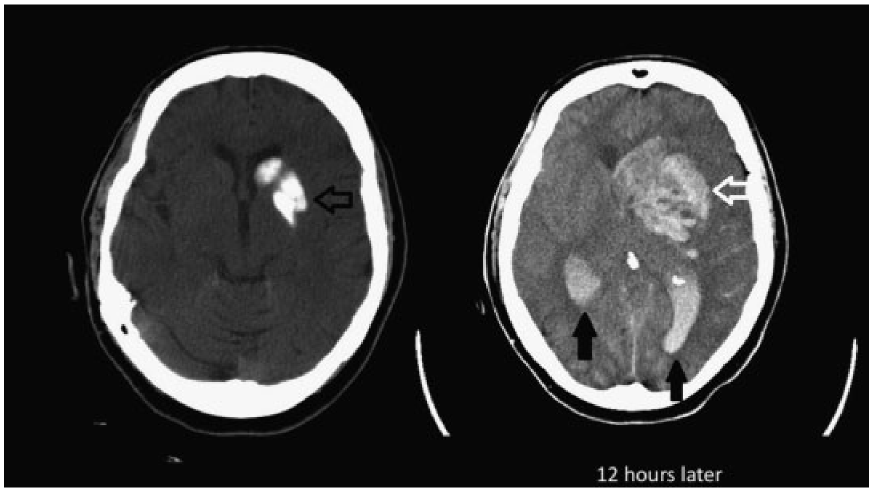

Figure 5 Microcatheter injection in the left MCA during stroke intervention. Postintervention noncontrast CT scan shows contrast staining of the left basal ganglia (open black arrow) after forceful microcatheter injections during stroke intervention. Such forceful injections are to be avoided at all costs during these types of procedures. Repeat CT scan 12 hours later demonstrates diffuse parenchymal (open white arrow) and intraventricular (solid black arrows) hemorrhage. CT, computed tomography.

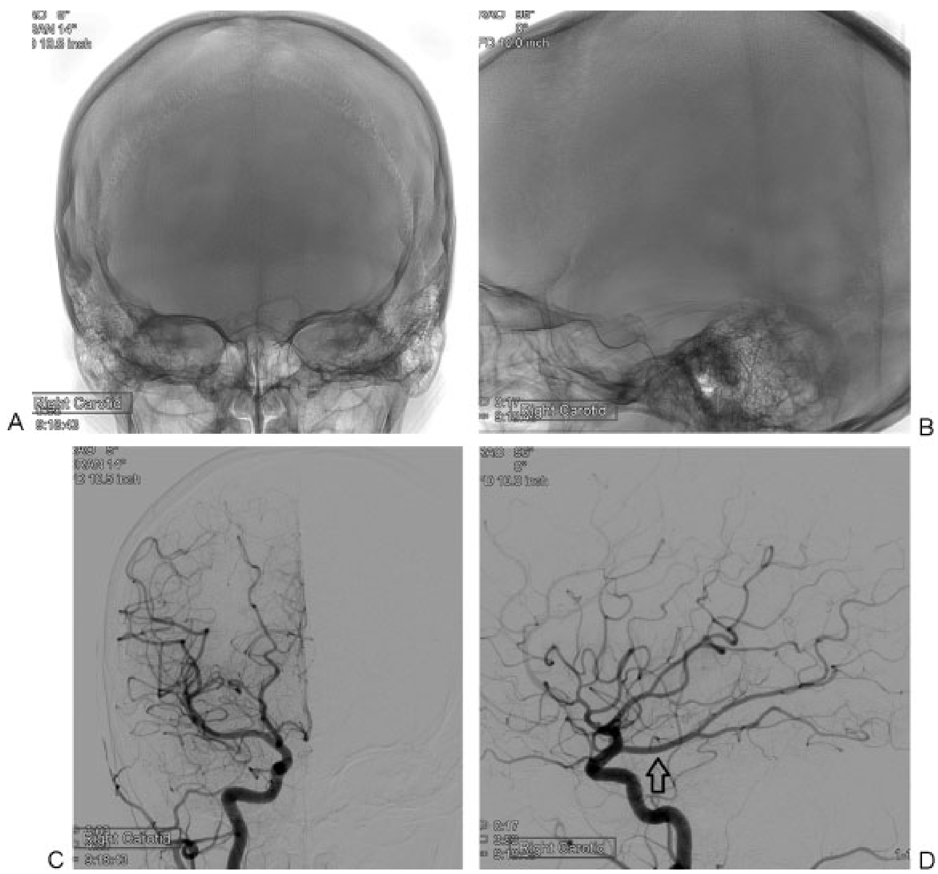

Figure 6 Standard (A) AP and (B) lateral positioning for anterior intracranial cerebral angiography of the right side with digital subtraction (C) AP and (D) lateral projections. Note the superimposition of the petrous bones on the orbits, and the fetal origin of the right PCA (arrow). AP, anteroposterior.

real-time 3D reconstruction of the vasculature. In the authors' experience, 3D imaging has allowed improved visualization of vascular pathology such as cerebral aneurysms, as well as increased confidence in excluding presence of aneurysms in overlapped areas. The injection rate is 4 to 5 mL/s for 20 to 25 mL total, and the image frame rate is 2 f/s.

For vertebral arteriograms, the standard projections are AP (Townes view) and lateral projections centered caudally

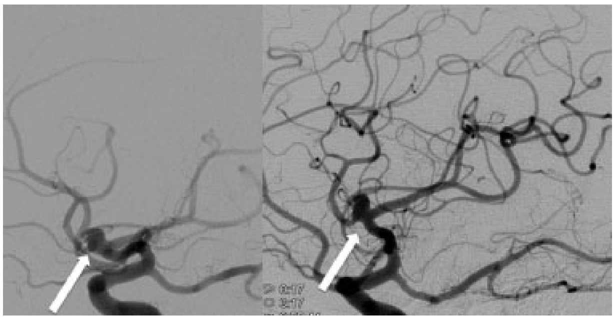

Figure 7 Stenvers view. The standard lateral projection demonstrates the MCA bifurcation aneurysm, but the Stenvers view provides much clearer view of location and base of the aneurysm (arrows).

and dorsally to cover the posterior circulation (►**Fig. 8**). In distinction to the anterior circulation, the petrous bones should be projected at the bottom or below the orbits to best visualize the basilar artery and its branches in the AP dimension. Retrograde reflux beyond the origin of the contralateral PICA is necessary to exclude the presence of contralateral PICA aneurysm. The injection rate is 5 to 7 mL/s for total of 8 to 10 mL total, and image frame rate is 2 f/s.

For intracranial arteriograms, image acquisition should include the venous phase to exclude venous pathology such as venous sinus thrombosis or arteriovenous malformation or fistula. After each automated pump injection, a neurological assessment is performed and documented. ►**Table 2** illustrates the common injection and image framing rates for various selective catheterizations; these rates are similar to the those reported from a survey of 90 neuroradiology program directors.[6] ►**Table 3** lists examples of catheters for various selective catheterizations, which is not meant to be an exclusive or an exhaustive list but to be used as examples.

Postprocedure Care

After diagnostic cerebral arteriogram is completed, routine CFA access care is recommended. Hemostasis may be accomplished with manual compression or any of the available percutaneous closure devices. The authors prefer StarClose SE (Abbott Vascular, Abbott Park, IL). After NA, a neurological examination should be performed and any changes should be documented. Significant neurological changes may require further evaluation with NA, CT, or magnetic resonance imaging. Sedation or anesthesia may limit neurological assessment in certain patients. Outpatients should be followed

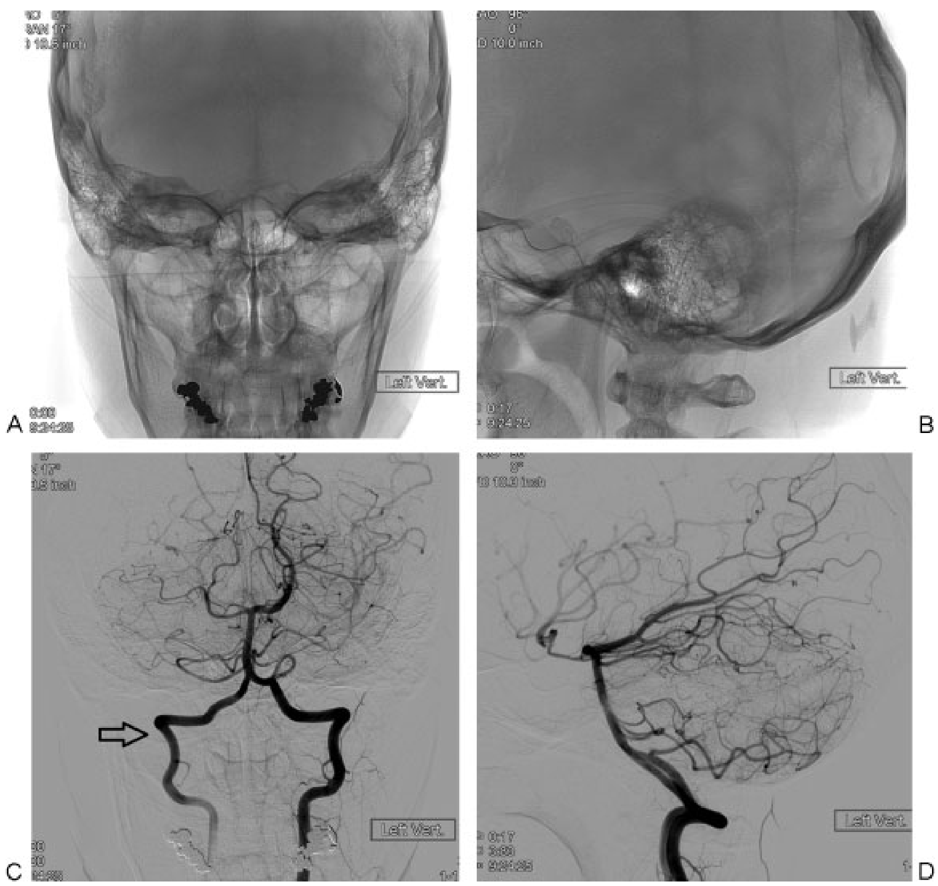

Figure 8 Standard (A) AP and (B) lateral positioning for posterior intracranial circulation with digital subtraction (C) AP and (D) lateral projections. Note the location of the petrous bones in relation to the orbits. Also, reflux caudal to the origin of the contralateral PICA (arrow) is recommended to exclude PICA origin aneurysm if the angiogram is being performed for subarachnoid hemorrhage. AP, anteroposterior; PICA, posterior inferior cerebellar artery.

Table 2 Contrast injection rates and imaging framing rates for common selective catheterizations in NA

	Contrast injection rate, (mL/s)/total mL	Framing rate, frames/s
Cervical arch	20/40	3
Extracranial ICA with catheter in the CCA	4–5/7–8	2
Cerebral angiogram with catheter in the CCA	7–8/11–12	2–3
ECA with the catheter in the ECA	4–5/6–7	2
Posterior cerebral angiogram with catheter in the vertebral artery	6–7/9–10	2

Abbreviations: CCA, common carotid artery; ECA, external carotid artery; ICA, internal carotic artery; NA, neuroangiography.

Table 3 Examples of catheter and wires for NA

	Catheters	Examples	Wires	Examples
Cervical arch	Multiside holed	VCF[a]	0.035 spring coiled	TDOC[a]
CCA	Angled	5 F Davis[a]	Glidewire	Glidewire[e]
		DAC[b]		
		H1H[a]		
	Reverse curve	Simmons 2[a]		
ECA	Angled	5 F Davis[a]	Glidewire	Glidewire[e]
		DAC[b]		
Intracranial ICA	Microcatheter	Prowler[c]	0.014 wire	Synchro[f]
		Renegade[d]		
	Sheath	6F Shuttle[a]		

Abbreviations: CCA, common carotid artery; ECA, external carotid artery; ICA, internal carotic artery; NA, neuroangiography.
Note: Operators are not limited to listed examples and similar catheters and wires may be substituted.
[a]Cook Medical, Bloomington, IN.
[b]Concentric Medical, Mountain View, CA.
[c]Codman & Shurtleff, Inc., Raynham, MA.
[d]Boston Scientific, Natick, MA.
[e]Terumo Interventional Systems, Somerset, NJ.
[f]Stryker Neurovascular Freemont, CA.

longitudinally with the IR. Patients who have undergone an intervention should be admitted either to the interventional radiology, neurology, or neurointensive care services depending on the procedure. Regardless of the admitting service, coordinated care among the appropriate clinical services is prudent.

Complications

Diagnostic NA can be performed safely with a low level of complications. For diagnostic NA, the rate of complications is higher in older patients and those with severe atherosclerosis, vasculitis, symptomatic cerebrovascular disease, or acute subarachnoid hemorrhage. Increase in length of the procedure, number of catheter exchanges, size of catheters, and the amount of contrast used are associated with higher rates of complications.[7] NA complications are divided into neurological and nonneurological complications. Stroke is the main neurological complication and can be split into transient ischemic attack (TIA) (deficits lasting < 24 hours), reversible stroke (1–7 days), and permanent stroke (deficits lasting longer than 7 days) (►**Fig. 9**). According to a cooperative statement issued by the Society of Interventional Radiology, American Society of Interventional and Therapeutic Neuroradiology, and American Society of Neuroradiology, the reported range of reversible neurological deficits is 0 to 2.3% and that of permanent neurological deficit is 0 to 5%.[7] A recent retrospective study of 1,715 diagnostic NA cases at a high-volume neurointerventional department showed nearly 0% neurological complications: there were no reversible or permanent strokes, with one TIA (0.06%).[8] The cooperative position statement suggests complication specific thresholds to be 2.5 and 1% for reversible and permanent neurological deficits, respectively.[7] Operators wishing to perform NA should be able to verify these excellent results.

Nonneurological complications for NA are renal failure, arterial occlusions requiring intervention, arteriovenous fistula, and hematoma requiring transfusions or surgical

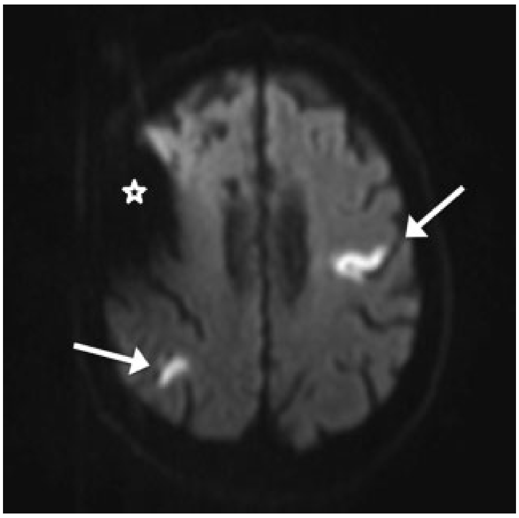

Figure 9 Diffusion-weighted axial MR image shows bilateral areas of restricted diffusion (white arrows) 2 days after NA. The patient had persistent right upper extremity weakness after rehabilitation. Artifact in the right anterior hemisphere (star) is due to existing ventricular drain.

evacuation; reported rates are 0 to 0.15%, 0 to 0.4%, 0.01 to 0.22%, and 0.25 to 1.5%, respectively.[7] In the same study of 1,715 diagnostic NA, the catheter-related complication rate was 0.5%, with four patients with extracranial vessel dissection (0.2%), one of which needed emergent stent placement. Sheath-related complications were noted in five patients (0.3%), three of which needed surgical repair.[8]

Conclusions

NA is an important component of neurovascular disease diagnosis and management. Understanding of neurological anatomy and disease, careful catheter technique, and patient care are critical to ensure safe outcomes. As illustrated above, there is much overlap with PA. As such, with appropriate knowledge and experience, interventional radiologists are well equipped to participate in many aspects of NA as dictated by operator experience and institutional need.

Conflict of Interest
Authors have no conflict of interest.

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