ACR–ASNR–SIR–SNIS PRACTICE PARAMETER FOR THE PERFORMANCE OF ENDOVASCULAR THROMBECTOMY AND REVASCULARIZATION IN ACUTE STROKE

PREAMBLE

This document is an educational tool designed to assist practitioners in providing appropriate radiologic care for patients. Practice Parameters and Technical Standards are not inflexible rules or requirements of practice and are not intended, nor should they be used, to establish a legal standard of care[1]. For these reasons and those set forth below, the American College of Radiology and our collaborating medical specialty societies caution against the use of these documents in litigation in which the clinical decisions of a practitioner are called into question.

The ultimate judgment regarding the propriety of any specific procedure or course of action must be made by the practitioner considering all the circumstances presented. Thus, an approach that differs from the guidance in this document, standing alone, does not necessarily imply that the approach was below the standard of care. To the contrary, a conscientious practitioner may responsibly adopt a course of action different from that set forth in this document when, in the reasonable judgment of the practitioner, such course of action is indicated by variables such as the condition of the patient, limitations of available resources, or advances in knowledge or technology after publication of this document. However, a practitioner who employs an approach substantially different from the guidance in this document may consider documenting in the patient record information sufficient to explain the approach taken.

The practice of medicine involves the science, and the art of dealing with the prevention, diagnosis, alleviation, and treatment of disease. The variety and complexity of human conditions make it impossible to always reach the most appropriate diagnosis or to predict with certainty a particular response to treatment. Therefore, it should be recognized that adherence to the guidance in this document will not assure an accurate diagnosis or a successful outcome. All that should be expected is that the practitioner will follow a reasonable course of action based on current knowledge, available resources, and the needs of the patient to deliver effective and safe medical care. The purpose of this document is to assist practitioners in achieving this objective.

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1 *Iowa Medical Society and Iowa Society of Anesthesiologists v. Iowa Board of Nursing, 831 N.W.2d 826 (Iowa 2013) Iowa Supreme Court refuses to find that the "ACR Technical Standard for Management of the Use of Radiation in Fluoroscopic Procedures (Revised 2008)" sets a national standard for who may perform fluoroscopic procedures in light of the standard's stated purpose that ACR standards are educational tools and not intended to establish a legal standard of care. See also, Stanley v. McCarver, 63 P.3d 1076 (Ariz. App. 2003) where in a concurring opinion the Court stated that "published standards or guidelines of specialty medical organizations are useful in determining the duty owed or the standard of care applicable in a given situation" even though ACR standards themselves do not establish the standard of care.*

I. INTRODUCTION

This practice parameter was developed and written with the collaboration of the American College of Radiology (ACR), the American Society of Neuroradiology (ASNR), the Society of Interventional Radiology (SIR), and the Society of NeuroInterventional Surgery (SNIS).

This practice parameter will focus on several areas: (i) recent advances in endovascular stroke care, (ii) qualifications and responsibilities of the endovascular stroke team, (iii) recommendations regarding equipment and instrumentation, (iv) technical aspects and/or recommendations regarding performance and reporting of the endovascular procedure and periprocedural care, and (v) recommendations on quality control and performance improvement.

Every year in the United States, an estimated 795,000 people suffer an ischemic stroke. It is estimated that 30%, or nearly 240,000, of these strokes will be caused by an emergent large-vessel occlusion (ELVO) affecting the intracranial and cervical internal carotid artery, the proximal middle, anterior, and posterior cerebral arteries, the intracranial vertebral arteries, or the basilar artery [1-3,87]. The sequelae are devastating: ELVO strokes are associated with greater symptoms and worse outcomes, for a disease that, overall, remains a leading cause of death and disability and has been associated with indirect and direct societal costs of up to $34 billion [4,5].

The status of endovascular stroke therapy changed significantly in 2015 with the publication of 5 randomized controlled trials that showed a substantial benefit of mechanical thrombectomy in select patients presenting with acute neurological symptoms attributable to a large-vessel occlusion within 6 hours from time of symptom onset [6-10]. There are an estimated 24 ELVO strokes per 100,000 people per year in the United States. Some regions in the country are performing 10 to 12 endovascular stroke procedures per 100,000. The national average is between 3 and 6 endovascular stroke interventions per 100,000 people [3]. These estimates suggest a potential for significant growth in the endovascular stroke procedure volumes.

Endovascular treatment of ELVO acute ischemic stroke (AIS) has evolved rapidly in the last decade. With the advent of endovascular treatments, patients with ELVO AIS, a condition that carries severe morbidity and mortality, can recover significant neurologic function. New thrombectomy devices, imaging techniques, and systems of care have revolutionized the care of patients who experience stroke. Within the first 6 hours after onset of symptoms, many patients can be treated safely and effectively, with good clinical outcomes achieved in a significant number of cases [88,89,90]. Additionally, clinical trial results show that many patients who awaken with stroke symptoms or are treated between 6 and 24 hours of symptom onset may also benefit provided they have a favorable imaging profile (eg, CTP Assessment with Clinical Mismatch in the Triage of Wake-Up and Late Presenting Strokes Undergoing Neurointervention with Trevo [DAWN] or The Endovascular Therapy Following Imaging Evaluation for Ischemic Stroke [DEFUSE-3] [11,12]). This further increases the number of patients eligible for mechanical thrombectomy. In 2022 and 2023, trials examining the efficacy of treatment of patients with posterior circulation strokes and relatively large core anterior circulation strokes have further expanded the population that may benefit from thrombectomy [13-17]. The practice parameter outlined below will evolve based on new clinical trial results and other lines of evidence.

For additional information on definitions, see Appendix A.

II. INDICATIONS AND CONTRAINDICATIONS

A. Summary

1. Class 1 recommendations based on *Level A* indications for endovascular revascularization include, but are not limited to:
    a. Treatment of adult patients with major stroke symptoms (National Institutes of Health Stroke Scale (NIHSS) score of >6) caused by large-vessel occlusion (internal carotid artery (ICA) or M1 segment of the middle cerebral artery [MCA]).
    b. Endovascular treatment, which can be initiated within 6 hours of symptom onset based on demonstration of intracranial large-vessel occlusion and lack of imaging contraindications or which can be initiated 6– 24 hours after symptoms onset based on advanced imaging criteria.

2. Current contraindications for endovascular intervention based on a consensus of expert opinion include, but are not limited to:
    a. Evidence of a large irreversible infarction in the territory of the index vessel.
    b. Severe baseline functional (cognitive and/or medical) disability that would render the potential benefits of revascularization negligible.
    c. Presence of intraparenchymal hemorrhage in the territory perfused by the ELVO at the time of imaging evaluation.

3. There is mounting evidence that suggests that some patients who do not meet Class 1 *Level A* eligibility criteria may also benefit from treatment. Thus, it may be reasonable to treat some patients outside Class 1 recommendations.

II. INDICATIONS AND CONTRAINDICATIONS

B. Discussion

This section of the practice parameter concerns the clinical indications for endovascular revascularization in patients with acute arterial ischemic stroke. Guidelines concerning the technical aspects of revascularization are covered elsewhere.

The indications and contraindications described above have been endorsed by numerous professional societies focused on cerebrovascular diseases that include physicians in the fields of neuroradiology, interventional radiology, neurointerventional surgery, neurosurgery, and neurology. Although these standards are the current Class 1 recommendations, some publications indicate that up to 40% or 50% of the patients treated are outside of the Class 1 recommendations of the American Heart Association (AHA) [18].

The inclusion and exclusion criteria are based on the following concepts:

- Patient selection for endovascular stroke treatment presumes that the potential morbidity and mortality of the untreated stroke is greater than the risk of intervention. For example, a minor stroke that is unlikely to cause significant long-term disability does not generally justify an invasive procedure that may be more likely to cause greater harm than the stroke itself.
- NIHSS is the widely accepted clinical means of quantifying stroke severity. The current accepted definition of major stroke is NIHSS >/= 6
- The likelihood of a good clinical outcome in stroke depends on the timeliness of cerebral reperfusion.

1. Patient Characteristics

   Stroke Severity

   The NIHSS cutoff determining "major stroke symptoms" has evolved over time with a general trend toward treating lower NIHSS. Early endovascular stroke trials that focused on intra-arterial thrombolysis defined major stroke as having an NIHSS =10 [19]. This threshold was based on the low likelihood of a good clinical outcome when patients at or above the threshold stroke severity were not treated. Subsequent trials lowered the definition of major stroke to any stroke having an NIHSS =8. This change was also based on the observation that patients with strokes less severe than the selected severity threshold had a reasonable chance of a good clinical outcome if left untreated.

    - Most recently, the definition of major stroke for the purposes of endovascular therapy selection has been lowered to NIHSS =6 [7,9,20,93,94]. The presumption is that patients with minor strokes defined as NIHSS =5 are less likely to have a poor neurological outcome than if they undergo an endovascular procedure. However, some practitioners choose to treat patients with low NIHSS, particularly in the context of disabling aphasia or where there is concern of worsening NIHSS in the setting of ELVO with fluctuating luminal patency.

   Although this guideline is well founded in principle, there are some patients who present with minor stroke symptoms due to a large-vessel occlusion who clinically worsen late in the course of their stroke because of collateral failure. Although such patients may have benefited from early treatment, they are often not eligible for treatment when their symptoms worsen late in their clinical course (6 to 24 hours) because they fall outside currently established temporal windows for therapeutic opportunity.

- Another category of patients with minor stroke symptoms who may benefit from endovascular revascularization are those patients in whom intravenous (IV) thrombolysis is contraindicated. Given the absence of any treatment options, such patients could reasonably be offered endovascular therapy. However, it is not clear whether the risks of endovascular treatment are less than the risks of disease natural history in such patients.

Although further research is needed to determine when endovascular therapy should be considered for patients presenting with minor stroke symptoms, preliminary data suggest that patients with minor stroke symptoms and large-vessel occlusion may benefit from mechanical thrombectomy [21]. As the risks and benefits of treatment evolve, so might the pool of patients for whom thrombectomy may be considered reasonable. For example, patients with a disabling defecit such as isolated aphasia or hemianopia may be reasonable candidates for thrombectomy despite lower total NIHSS scores [22].

- Select patients with large-vessel occlusion and an NIHSS <5 may still benefit from endovascular therapy.

Age

All clinical trials of endovascular therapy for acute stroke have been conducted in adult patients who are at least 18 years of age. On the other end of the age spectrum, 3 of the 5 landmark endovascular versus medical therapy randomized trials published in 2015 did not exclude elderly patients (MR CLEAN, ESCAPE, EXTEND-IA). Data do not advocate for thrombectomy being withheld from patients based on advanced age alone.

- Although patients younger than 18 years of age were not included in these clinical trials, endovascular stroke therapy is considered reasonable in this population on a case-by-case basis according to expert consensus [23].
- Endovascular therapy should not be withheld based on advanced age alone [12,24-26].

Time

It is clear from clinical stroke trials conducted to date that the likelihood of a good clinical outcome depends on the timeliness of cerebral reperfusion.

- Data combined from multiple randomized controlled trials using modern stent retriever and aspiration devices have suggested that improved clinical outcomes are possible if cerebral reperfusion is achieved within 7.3 hours of symptom onset in a heterogeneous meta-analysis [27].
- Additionally, for patients with favorable imaging between 6 and 24 hours of onset, 2 randomized trials have shown benefit with thrombectomy compared with best medical therapy [12,28].
- Patients can be eligible for endovascular therapy for up to 24 hours from stroke onset; however, the imaging criteria for patients between 6 and 24 hours may be more selective than those in the first 6 hours [29].
- Case series have suggested that treating patients with favorable imaging beyond 24 hours from stroke onset can be successful. Further research on this should provide clearer guidance in the future [91,92].
- Prior studies have not established the safety of intra-arterial thrombolytic administration to stroke patients who are more than 6 hours from last seen normal [30].

2. Imaging Characteristics

The goal of imaging in the setting of acute stroke is to (a) exclude hemorrhage and stroke mimics such as a tumor from those with true acute ischemic presentations, (b) estimate the size of ischemic core, (c) and assess for a proximal occlusion of an intracranial artery thought to be amenable to endovascular therapy. Inclusion of the aortic arch and extracranial vasculature in the vascular assessment allows for identification of additional arterial findings relevant to mechanical thrombectomy, such as anatomy for endovascular access (including variants or other findings posing technical challenges), or potential for carotid or vertebral arterial disease, either as a cause for the proximal intracranial arterial occlusion or requiring consideration in the technical aspects of successful recanalization (eg, carotid stenosis or tandem carotid occlusion).

Although MRI/MR angiography (MRA) and CT/CT angiography (CTA) can both be used for this assessment, most centers will likely perform CT/CTA because of the ubiquitous nature of this technology, ease of performing brain and vascular imaging, and the relative lack of contraindications to imaging, as can occur with MR-based protocols [31].

It is well recognized that, although CTA does add time to the imaging protocol, the benefits of this vascular imaging for clinical decision making outweigh potential risks and reduce overall time from imaging to decision making for endovascular management. All efforts should be made to minimize the delay in performing this vascular imaging. Thrombolytic therapy can be started immediately following the noncontrast CT, if the patient is determined eligible, while the CTA is being planned. In centers with appropriate safety protocols in place, this can be done with the patient remaining in the CT scanner and has been shown to reduce door to needle times [32]. Sites without immediate access to CTA should perform a noncontrast CT to ensure that IV thrombolytic therapy decision making is not unduly delayed and should not delay appropriate care in order to complete the CTA.

Infarct Size

A large area of infarction, based on initial neuroimaging workup, has typically been considered a relative contraindication for revascularization. In such cases, the likelihood of procedure-related harm due to reperfusion resulting in hemorrhagic transformation may be higher than in those with smaller baseline infarction. Infarction involving one-third or more of the MCA territory has classically been considered a contraindication to endovascular treatment based on this principle. In an effort to standardize imaging criteria to support this guideline, the ASPECTs was developed. Although an ASPECTS <6 or other evidence of a large-core infarction at presentation is generally considered a contraindication to endovascular revascularization in the past, there is increasing controversy regarding the reliability of CT-based ASPECTS to determine the extent of irreversible infarction [33-35]. Endovascular revascularization in patients with large ischemic strokes has been shown in a limited number of trials with specific inclusion criteria to result in better functional outcomes than medical management alone but may be associated with vascular complications[13,14]. More recently, three randomized controlled trials have shown that patients with anterior circulation ELVO and a large ischemic core, defined as ASPECTS 3–5 and/or infarct-core volume of =50 mL or 70–100 mL [102-104], had better functional outcomes with thrombectomy than with medical management alone [13-15]. Some recent work (SELECT2, ANGEL-ASPECT, TENSION), however, has demonstrated some improvement in rates of functional independence and considerable reduction in modified Rankin Scale (mRS) 5 outcomes in patients with large core infarcts treated with mechanical thrombectomy. Further investigation is ongoing in this patient population [105, 106,13,14].

Significant subacute infarction or hemorrhage within the territory of an occluded target artery due to a prior event predating the index presentation should be considered a contraindication to revascularization of the occluded vessel. In such cases, reperfusion of an affected brain may precipitate lethal or severely disabling cerebral hemorrhage within the territory of the index vessel, negating any benefit of revascularization.

Vascular Imaging

Facilities that perform endovascular stroke treatment should have capacity to provide head/neck vascular imaging at the same time as the initial brain imaging. Assessment of the intracranial and extracranial arteries, including the aortic arch, can be done using single-phase technique. CT perfusion or multiphase CTA may also form part of the initial cross-sectional imaging workup of a stroke patient. CT perfusion and multiphase CTA were used to identify patients with large irreversible infarction for exclusion in randomized trials [7,8,40,93,94]. There are differing methods and grading scales for CTA, with emphasis on determining the presence and robustness of pial-to-pial collaterals. There is also recognized variation in CT perfusion map outputs among different vendor software packages. The optimal use of these advanced imaging techniques is not established by *Level I*, Class A evidence. Based on currently published data, performing multiphase CTA and/or CT perfusion is not required to identify the criteria for inclusion or exclusion of a patient from thrombectomy in current clinical practice (except in the later treatment window of 6–24 hours after last known well, where advanced imaging techniques including perfusion have been validated), although these may be helpful in some situations, such as for those patients being considered for transfer to a center capable of performing endovascular therapy.

- Large-core infarct (eg, ASPECTS <6 or ischemic core volume >50–70 mL) is a relative contraindication to endovascular revascularization, whether assessed by CT- or MR-based techniques.
- Any hemorrhage is a contraindication for administration of thrombolytic medications.
- Intracranial hemorrhage is also generally considered to be a contraindication for mechanical thrombectomy except in selected patients in whom the potential benefit of intervention outweighs the risk of revascularization.

Occlusion Location

As noted above, currently supported indications for endovascular stroke therapy endorse specific anatomical criteria involving large artery occlusions within the anterior circulation. These anatomical criteria have been derived from a synthesis of data from large randomized clinical trials subjected to rigorous peer review.

- There is consensus that patients with cervical or intracranial ICA or M1 segment MCA occlusion are appropriate for endovascular treatment. However, it has been proposed that treatment of smaller vessels located more distally in the anterior circulation should be considered reasonable, but there is significant variability of opinion as to which vessels constitute reasonable targets for endovascular therapy.
- Some arterial segments may be regarded as controversial. For example, *Level A* evidence currently suggests that M2 lesions do not benefit in aggregate from treatment [24,41]. However, some post hoc analyses suggest that there may be certain subgroups of patients with M2 occlusions that may benefit from treatment. There is mounting evidence that the proximal M2 segments of the MCAs are suitable targets for endovascular revascularization in patients with an associated moderate to severe clinical deficit [42-46].

One of the difficulties encountered in analysis of modern clinical trial data concerns the inconsistent definition of proximal M2 occlusion. Case series and post hoc analyses of randomized clinical trial data inconsistently show improved clinical outcomes in successfully revascularized M2 occlusions depending on the size of the affected vascular territory. Nonetheless, there is an absence of Class I evidence supporting the practice of M2 revascularization owing to the small number of patients with isolated M2 occlusions in recent positive clinical trials for endovascular stroke therapy. However, consensus of expert opinion supports the indication for endovascular revascularization of a proximal M2 occlusion in patients with an associated moderate to severe clinical deficit [22,47].

Post hoc analyses of several trials indicate that M2 division occlusions affecting a cortical lobar equivalent probably benefit from thrombectomy; smaller MCA branch occlusions may or may not [45].

Two recently published trials evaluating thrombectomy for posterior circulation acute ischemic strokes ATTENTION [17] and BAOCHE [16] have demonstrated that thrombectomy performed =12 or 6–24 hours after onset, respectively, improved functional outcome over medical therapy. However, thrombectomy was associated with procedural complications and had a higher rate of symptomatic intracranial hemorrhages. The benefit of thrombectomy for basilar artery occlusion (BAO) in terms of 90-day mRS ordinal shift has the potential to be similar to thrombectomy for anterior circulation ELVO [50].Based on the positive BAO trials, selection criteria would include moderate to severe deficits (NIHSS =10), absence of a large infarct in the posterior circulation and specifically in the brain stem, and symptom onset within 24 hours.There is currently no consensus on a preferred method to measure the extent of posterior circulation infarction. Some interventionalists may also choose to treat BAOs beyond 24 hours given the potentially devastating results of untreated BAO.

A combination of patient characteristics (age, NIHSS, mRS) and infarct size and location can be used to exclude patients from thrombectomy.

For the pregnant or potentially pregnant patient, see the ACR–SPR Practice Parameter for Imaging Pregnant or Potentially Pregnant Patients with Ionizing Radiation [51].

III. QUALIFICATIONS AND RESPONSIBILITIES OF PERSONNEL

Generally, the health professionals involved in the care of patients with stroke must be familiar with the signs and symptoms of stroke.

See the ACR–ASNR–SIR–SNIS Practice Parameter for the Performance of Diagnostic Cervicocerebral Catheter Angiography in Adults [52].

III. QUALIFICATIONS AND RESPONSIBILITIES OF PERSONNEL

A. Physician

Physicians providing emergent endovascular intervention for AIS are required to have appropriate training and experience for the performance of neuroangiography and neuroendovascular therapy, which are essential for safe and efficient stroke patient management. Although the physician qualifications below are tailored toward new practitioners, it should be recognized that there are current practitioners (who may be board certified or board eligible in either radiology, neurology, or neurosurgery) having trained prior to, or outside of, established formal neuroendovascular training programs, and having acquired the necessary skills listed below to perform safe and effective endovascular stroke treatment. Nonetheless, all neuroendovascular specialists are required to participate in maintenance of certification and maintenance of qualification requirements, as listed below.

Endovascular thrombectomy and revascularization in patients with acute stroke must be performed by or under the supervision of and interpreted by a physician who has met the qualifications of the ACR–ASNR–SIR–SNIS Practice Parameter for the Performance of Diagnostic Cervicocerebral Catheter Angiography in Adults [52], as well as the qualifications below:

1. Accreditation Council for Graduate Medicine Education (ACGME)– or Royal College of Physicians and Surgeons of Canada– (RCPSC) accredited residency or fellowship training (in radiology, neurology, or neurosurgery), which should include documented training in the diagnosis and endovascular management of acute stroke. Those physicians who did not have such adequate training during their residencies should spend an additional period of training in clinical neurosciences and neuroimaging, focusing on the diagnosis and management of acute stroke, the interpretation of cerebral angiography, and neuroimaging. We encourage practitioners to meet published training and procedural requirements, acknowledging that the ACR, ASNR, SIR, and SNIS standards may have differing training and procedural requirements.

or

2. Focused training in interventional neuroradiology (also termed endovascular neurosurgery or interventional neurology) under the direction of a neurointerventionalist (with neuroradiology, neurology, or neurosurgical training background) at a high-volume center. It is preferred that this is a dedicated time . A training program accredited by a national accrediting body is also strongly preferred but not required.

Within these programs, specific training for endovascular therapy for AIS should be performed, including obtaining appropriate access even in challenging anatomy, microcatheter navigation in the cerebral circulation, knowledge, and training of the use of stroke-specific devices, and complication avoidance and management. We encourage practitioners to meet published training and procedural requirements while acknowledging various societal standards may have differing training and procedural requirements. Nonaccredited fellowships are also expected to have adequate training to meet minimum procedure requirements.

3. Physicians meeting all of the qualifications in 1 or 2 above must also have the following:

   Documentation of competency in all aspects of the procedure and pre- and postprocedure care by the use of objective outcome-based tools related to angiographic experience as well as clinical outcome measures is necessary. Attestation of competency by a qualified stroke interventionalist who has observed the physician during the performance of thrombectomy procedures is required.
   For previously credentialed physicians who perform endovascular catheter-directed stroke procedures at their local institutions, they should have documented procedural and clinical outcomes that meet national standards and published evidence-based guidelines [53].
   The written substantiation should come from the chief of interventional radiology, the chief of neuroradiology, the chief of interventional neuroradiology, or the chair of the department of the institution in which the physician will be providing these services.[1] Substantiation could also come from a prior institution in which the physician provided the services, but only at the discretion of the current interventional, neurointerventional, or neuroradiology chief or of the chair who solicits the additional input. [1]At institutions in which there is joint (dual) credentialing across departments doing like procedures, this substantiation of experience should be done by the chairs of both departments to ensure equity of experience among practitioners when their training backgrounds differ.

Maintenance of Competence

Physicians must perform a sufficient number of overall procedures to maintain their skills. Continued competence should depend on participation in a quality improvement program. Consideration should be given to the physician’s lifetime practice experience.

Continuing Medical Education

The physician’s continuing education should be in accordance with the ACR Practice Parameter for Continuing Medical Education (CME) [55].

III. QUALIFICATIONS AND RESPONSIBILITIES OF PERSONNEL

B. Qualified Medical Physicist

A Qualified Medical Physicist is an individual who is competent to practice independently in one or more of the subfields in medical physics. The American College of Radiology considers certification, continuing education, and experience in the appropriate subfield(s) to demonstrate that an individual is competent to practice in one or more of the subfields in medical physics, and to be a Qualified Medical Physicist. The ACR strongly recommends that the individual be certified in the appropriate subfield(s) by the American Board of Radiology (ABR), the Canadian College of Physics in Medicine (CCPM), the American Board of Science in Nuclear Medicine (ABSNM), or the American Board of Medical Physics (ABMP).

A Qualified Medical Physicist should meet the ACR Practice Parameter for Continuing Medical Education (CME) [55].

The appropriate subfield of medical physics for this parameter is diagnostic medical physics (previous medical physics certification categories, including radiological physics, diagnostic radiological physics, and diagnostic imaging physics are also acceptable). (ACR Resolution 17, adopted in 1996 – revised in 2008, 2012, 2022, Resolution 41f)

III. QUALIFICATIONS AND RESPONSIBILITIES OF PERSONNEL

C. Non-Physician Radiology Provider (NPRP)

NPRPs are all Non-Physician Providers (eg, RRA, RPA, RA, PA, NP, ...) who assist with or participate in portions of the practice of a radiologist-led team (Radiologists = diagnostic, interventional, neurointerventional radiologists, radiation oncologists, and nuclear medicine physicians). The term "NPRP" does not include radiology, CT, US, NM MRI technologists, or radiation therapists who have specific training for radiology related tasks (eg, acquisition of images, operation of imaging and therapeutic equipment) that are not typically performed by radiologists.

The term 'radiologist-led team' is defined as a team supervised by a radiologist (ie, diagnostic, interventional, neurointerventional radiologist, radiation oncologist, and nuclear medicine physician) and consists of additional healthcare providers including RRAs, PAs, NPs, and other personnel critical to the provision of the highest quality of healthcare to patients. (ACR Resolution 8, adopted 2020).

III. QUALIFICATIONS AND RESPONSIBILITIES OF PERSONNEL

D. Radiologic Technologist

1. The technologist, together with the physician and nursing personnel, should be responsible for patient comfort and safety. The technologist should be able to prepare and position[1] the patient for the angiographic procedure. The technologist should obtain the imaging data in a manner prescribed by the supervising physician. The technologist should be knowledgeable in the archiving ("filming") of cases. The technologist should also perform regular quality control testing of the equipment under supervision of the physicist.
2. Technologists should be properly trained in the use of the angiographic equipment and endovascular devices employed in the institution. They should demonstrate appropriate knowledge of patient positioning, endovascular devices, angiographic imaging and archiving, radiation protection, angiographic contrast injectors, angiographic supplies, and physiologic monitoring equipment. Certification as a vascular and interventional radiologic technologist is one measure of appropriate training. The technologists should be trained in cardiopulmonary resuscitation and in the location and function of the resuscitation equipment.
3. Technologists should be certified by the American Registry of Radiologic Technologists or have an unrestricted state license and documented training and experience in catheter cerebral angiography.

[1]The American College of Radiology approves of the practice of certified and/or licensed radiologic technologists performing fluoroscopy in a facility or department as a positioning or localizing procedure only, and then only if monitored by a supervising physician who is personally and immediately available*. There must be a written policy or process for the positioning or localizing procedure that is approved by the medical director of the facility or department/service and that includes written authority or policies and processes for designating radiologic technologists who may perform such procedures. (ACR Resolution 26, 1987 – revised in 2007, Resolution 12m)

*For the purposes of this parameter, "personally and immediately available" is defined in manner of the "personal supervision" provision of CMS—a physician must be in attendance in the room during the performance of the procedure. Program Memorandum Carriers, DHHS, HCFA, Transmittal B-01-28, April 19, 2001.

III. QUALIFICATIONS AND RESPONSIBILITIES OF PERSONNEL

E. Sedation and Analgesia Services

If the patient is to undergo procedural sedation, a licensed provider must monitor the patient as their primary responsibility and in accordance with the ACR–SIR Practice Parameter for Minimal and/or Moderate Sedation/Analgesia [56]. Individuals should be trained in the location of and the use of the facility's resuscitation equipment and in institutional protocols for code team alerts. Licensed providers must be privileged by the institution to administer sedation. For those centers that do not routinely use anesthesia services for emergent stroke intervention, rapid access to anesthesia services on a 24/7 basis is needed for emergent airway management, as patients may deteriorate rapidly during the procedure [99].

III. QUALIFICATIONS AND RESPONSIBILITIES OF PERSONNEL

F. Nursing Services

Nursing services are necessary for monitoring the patient during the procedure in cases in which a qualified anesthesiologist or CRNA is not involved.

IV. SPECIFICATIONS OF THE EXAMINATION

A. Facilities and Resources

Endovascular therapy requires the patient to be at an experienced stroke center with rapid access to cerebral angiography and qualified stroke interventionalists. Although complications of endovascular stroke intervention rarely require urgent surgery, angiographic procedures should be performed in an environment in which necessary surgical intervention can be instituted promptly. This would be an acute care hospital with adequate neurointerventional, neurosurgery, vascular surgery, anesthesiology, and ancillary support [54].

IV. SPECIFICATIONS OF THE EXAMINATION

B. Preprocedural Care

a. Clinical Evaluation
   i. Clinical evaluation necessary for therapeutic decision making in the acute phase should be performed as appropriate, including, but not necessarily limited to, the following:
      1. Relevant history of present illness, including time that the patient was last known to be well
      2. Pertinent comorbidities and recent medications
      3. Assessment of premorbid functioning, including determination of mRS
      4. Assessment of neurological impairment, including determination of NIHSS
      5. Assessment of hemodynamic and airway stability, including basic vital signs
      6. Assessment for relevant drug and contrast allergies
   ii. Clinical evaluation in the acute phase should be performed expediently. Any clinical evaluation that is not necessary for decision making in the acute phase but would delay acute therapies should be deferred.

b. Laboratory Evaluation
   i. Laboratory evaluation has traditionally been considered in therapeutic decision making.
   ii. Serological evaluation in the acute phase should be performed expediently. Any serological tests that are not necessary for decision making in the acute phase but would delay acute therapies should be deferred.
   iii. Relevant laboratory data should be obtained and reviewed if possible without delaying treatment.

c. Radiological Evaluation
   i. Neurological imaging may be reasonably performed using CT/CTA or MRI/MRA, as dictated by institutional protocol, resource availability, and patient condition.
   ii. At a minimum, neurological imaging should be sufficient to allow identification of intracranial hemorrhage, extent of completed infarction, and location of vessel occlusion.
   iii. Additional neurological imaging for assessment of ischemic penumbra, such as perfusion imaging or multiphase CTA, may be performed as necessary, and particularly in patients 6 to 24 hours after symptom onset/last known well.
   iv. Neurological imaging necessary for therapeutic decision making in the acute phase should be performed expediently. Results should be communicated to other members of the stroke team

expediently. To the extent possible, effort should made to minimize the time elapsed between patient arrival and completion of neurological imaging. Any radiological studies that are not necessary for decision making in the acute phase but would delay acute therapies should be deferred.

v. Administration of iodinated contrast should not be delayed on account of unavailable serum creatinine result [57].

d. Informed Consent

i. Informed consent must be in compliance with all state or federal laws, as appropriate, and the ACR–SIR–SPR Practice Parameter on Informed Consent for Image-Guided Procedures [58].

e. Transport

i. Once the decision has been made to perform endovascular treatment of AIS, transport of the patient to an appropriately equipped procedure room should be performed expediently. To the extent possible, effort should be taken to minimize the time elapsed between patient arrival and arterial puncture.

IV. SPECIFICATIONS OF THE EXAMINATION

C. Intraprocedural Care

As with all aspects of patient care in acute stroke, patient safety and time to recanalization are parallel primary goals. Controversy continues regarding the appropriate approach to sedation and anesthesia with respect to the acute stroke patient [59]. We recommend that the choice and level of sedation/anesthesia be guided by the patient's condition and resources available. Furthermore, patients undergoing endovascular intervention for AIS should be monitored and managed in accordance with the Society for Neuroscience in Anesthesiology and Critical Care Expert Consensus Statement [60]. If the patient is to undergo procedural sedation, a licensed provider must monitor the patient as their primary responsibility. This person must maintain an appropriate record of intraprocedural monitoring and care, as described in the ACR–SIR Practice Parameter for Minimal and/or Moderate Sedation/Analgesia [56].

The team required to safely and expeditiously perform cerebrovascular recanalization should be qualified and experienced as outlined in Section IV.A. Members of this team should assist in performing, imaging, and archiving the procedure as needed.

To expedite recanalization, all nursing, technologist, sedation provider, and interventionalist duties that can be completed prior to patient arrival should be performed as such. In addition, we recommend that each member of the team familiarize themselves with the patient's medical history (including advanced directives), the patient's presentation, and the patient's current condition before the patient arrives in the angiography suite.

Upon patient arrival in the angiography suite, we recommend clear delegation of responsibilities to team members to allow parallel systems processes and reduce procedure time. A stroke-specific time-out should be performed. In addition to documentation of patient vital signs and medications during the procedure, intraprocedural documentation should include, at a minimum: angiography suite arrival time, arterial access time, time of first access to the site of occlusion, number of passes required to achieve recanalization, and time to recanalization with the corresponding modified treatment in cerebral ischemia (mTICI) score. Documentation should meet the requirements of the quality improvement program described in Section IX and stroke center requirements.

The choice of access, guiding catheter, use of aspiration, and embolic retrieval device are left to the interventionalist's clinical judgment and personal preference. The use of intra-arterial thrombolysis should be reserved for specific patient populations; however, these data are derived from clinical trials that no longer reflect current practice. In addition, a clinically beneficial dose of intra-arterial recombinant tissue plasminogen activator (r-tPA) is not established, and r-tPA does not have US FDA approval for intra-arterial use. Intra-arterial fibrinolysis should not be performed as an alternative to thrombectomy in patients who are candidates for primary mechanical thrombectomy [54].

IV. SPECIFICATIONS OF THE EXAMINATION

D. Postprocedural Care

Patients who undergo endovascular treatment, in general, require special postprocedural attention other than the expected access site and lower- or upper-extremity (depending on the access: femoral, radial, brachial, carotid) checks. This is usually accomplished in a multidisciplinary team approach, along with neurologists, intensive care physicians, and other specialties (hospitalist, vascular surgeon, neurosurgeon, cardiologist if needed). Ideally these patients should be admitted to a neuro–intensive care unit (neuroICU) or to a dedicated stroke unit where vital signs and neurological examination can be performed according to nationally accepted protocols [22]. It is a reasonable approach to keep these patients in the neuroICU/stroke unit care level for 24 hours or potentially longer due to comorbidities or stroke severity. Some patients with rapid neurological improvement and minor residual deficits after mechanical thrombectomy may be transferred to an acute care bed to continue stroke workup, and physical and occupational therapy. Patients with less severe strokes can be followed by serial clinical examination. Patients with severe strokes may have decreased levels of consciousness and may require (if not already) endotracheal intubation for airway protection. In these cases, neurological examinationsmay be unrevealing and serial imaging may be necessary within the first 12–72 hours to assess stroke extension, mass effect, and the need for decompressive craniectomy. Dual-energy CT may help distinguish hemorrhage from contrast staining, when available [61,62].

Blood pressure (BP) control after endovascular treatment is important; however, the ideal numbers are still a matter of debate. Higher BP may increase the risk of hemorrhagic conversion and lower BP may increase the risk of infarct expansion in hypoperfusion states [63-65]. The existing data regarding BP parameters in acute stroke derive from the guidelines for IV thrombolytic therapy. According to American Heart Association/American Stroke Association guidelines [22], the recommended BP target post-IV tPA or IV Tenecteplase (TNK) is systolic BP < 185 mmHg and diastolic BP < 110 mmHg for 24 hours. However, after successful endovascular treatment (mTICI 2b/c and 3), because of the complete or near-complete reperfusion of the cerebral tissue, higher BP parameters may increase the theoretical risk of hemorrhage. In these cases, it seems reasonable to consider lower BP parameters despite the lack of evidence.

A significant number of patients with acute stroke from ELVO have a cardioembolic source, such as atrial fibrillation. In these patients, anticoagulation should be initiated as soon as it is deemed clinically safe to do so [66]. The timing of when to restart or start these medications is controversial because of the risk of hemorrhagic transformation inherent to infarcted brain parenchyma. Temperature should be monitored, fever should be controlled, and etiology should be sought out.

Patients with acute stroke benefit from tight glycemic control. The Glycemia in Acute Stroke study showed that hyperglycemia (>155 mg/dL) was associated with poor outcome and death at 3 months [67]. The goal of glycemic control should be normoglycemia (80–120 mg/dL). The AHA/ASA guidelines recommend treatment of hypoglycemia (<60 mg/dL). For patients with hyperglycemia, it is recommended to achieve blood glucose levels in a range of 140–180 mg/dL [22]. Renal function should be monitored as some of these patients are at risk for contrast-induced nephropathy. Temperature control is also important, and sources of hyperthermia (temperature > 38°C) should be identified and treated [22]. Postprocedural lab work in general demonstrates some degree of hemodilution; however, because most of the endovascular stroke treatments performed currently require the use of large sheaths and may have been performed in patients that have received thrombolytic therapy or anticoagulation, one should be attentive to signs of possible access site or retroperitoneal hematoma. Despite the lack of evidence specifically in patients with acute stroke treated with endovascular techniques, a systematic review of blood transfusions in neurocritical care patients found that hemoglobin concentrations as low as 7 g/dL are generally well tolerated [68,69]. However, other studies suggest that blood loss during endovascular therapy might correlate with worse outcomes [70].

V. DOCUMENTATION

Reporting should be in accordance with the ACR–SIR–SPR Practice Parameter for the Reporting and Archiving of Interventional Radiology Procedures [71].

Specific preprocedure information that should be available in the medical record includes clinically significant history, including indications for the procedure; premorbid functioning, ideally using mRS; degree of neurological impairment and other pertinent physical examination findings prior to treatment, including determination of NIHSS; findings of pertinent diagnostic imaging studies; and laboratory data. Specific postprocedure information that should be available within the medical record includes extent of angiographic recanalization, ideally using mTICI score, and degree of neurological impairment following treatment, including determination of NIHSS within 24 hours of treatment and mRS at 90 days after treatment, when possible. Documentation should meet the requirements of the quality improvement program described in Section IX.

VI. EQUIPMENT SPECIFICATIONS

There are multiple technical requirements that are necessary to ensure safe and successful endovascular treatment of AIS. These include adequate angiographic and interventional equipment and institutional facilities, physiologic monitoring equipment, and support personnel.

VI. EQUIPMENT SPECIFICATIONS

A. Procedural Equipment and Facilities

The following are considered the minimum equipment requirements for performing endovascular treatment of AIS. In planning facilities for these procedures, equipment and facilities more advanced than those outlined below may be desired to improve outcomes and reduce duration of the procedures. In general, at a minimum, the facility should include:

1. Fixed angiographic equipment with a high-resolution flat-panel detector (preferred) or image intensifier and image monitor with digital subtraction angiographic and roadmapping capabilities. Biplane capability is recommended to guide interventions and to reduce contrast load and time of the procedure. Equipment requirements are the same as those for the performance of diagnostic cervicocerebral angiography [52]. Digital angiographic systems without subtraction and roadmapping capability and older film-based systems are unacceptable for these procedures, except in the rare event that transfer to another system or institution with such capabilities would severely delay care. If such a system is employed as a backup for a more capable system, its actual use for endovascular treatment of AIS should be monitored with the expectation that this situation should be very rare. Imaging data should be acquired and permanently recorded on an archival digital storage medium that allows retrieval and review. It is highly desirable to be able to record and archive images used for guidance and decision making during the procedure, including last-image-hold images and fluoroscopy loops. Imaging, image recording, and archiving must be consistent with the as low as reasonably achievable (ALARA) radiation safety philosophy. Use of last image hold, fluoroscopy loops, and pulsed fluoroscopy are recommended for dose reduction. Small focal spots for high-resolution imaging and adjustable frame rates are necessary. The available field of view should be able to fit the whole head in frontal and lateral projections, with acknowledgement that some biplane neuroangiography systems employ a slightly smaller lateral detector to facilitate multiangle oblique imaging. Modern low-dose digital subtraction angiography settings should be applied when possible, but high-dose settings should be available for situations that require increased diagnostic sensitivity. Rotational angiography and flat-panel detector CT imaging are desirable to facilitate interventions and identify intraprocedural cerebral hemorrhage, respectively.

2. Adequate interventional and angiographic supplies, such as thrombectomy devices (eg, stent retrievers and aspiration catheters), vascular stents, embolic protection devices, angioplasty balloons, catheters, guidewires, needles, flush systems, hemostatic devices, introducer sheaths, closure devices, and biohazard disposal systems.

3. An angiographic injector capable of varying injection volumes and rates with appropriate safety mechanisms (pressure monitoring) to prevent overinjection.

4. An angiography suite large enough to allow uncomplicated patient transfer from the bed to table and to

allow room for the procedure table, monitoring equipment, and other hardware, such as IV pumps, respirators, anesthesia team and equipment, oxygen tanks, suction, and gases. There should be adequate space for the operating team to work unencumbered on either side of the patient and for the circulation of other technical staff in the room without contaminating the sterile conditions.

5. An area within the institution appropriate for patient evaluation and preparation before the procedure. Appropriate emergency equipment and medications must be immediately available to treat adverse reactions associated with administered medications and/or procedural complications. Immediate access to a CT scanner is necessary to evaluate for potential cerebral hemorrhage, edema, and hydrocephalus. The equipment should be monitored and medications inventoried for drug expiration dates on a regular basis. The equipment, medications, and other emergency support must also be appropriate for the range of ages and sizes in the patient population.

VI. EQUIPMENT SPECIFICATIONS

B. Physiologic Monitoring and Resuscitation Equipment

1. Appropriate equipment should be present in the angiography suite to allow for monitoring the patient's heart rate, cardiac rhythm, and BP. For facilities using sedation, a pulse oximeter must be available (see the ACR–SIR Practice Parameter for Minimal and/or Moderate Sedation/Analgesia [56]). Appropriate equipment and supplies to support the safe performance of general anesthesia should be available.

2. Emergency resuscitation equipment and drugs should be immediately available and include the following: a defibrillator, oxygen supply and appropriate tubing and delivery systems, suction equipment, tubes for endotracheal intubation, laryngoscope, ventilation bag-valve-mask apparatus, and central venous line sets. Drugs for treating cardiopulmonary arrest, contrast reaction, vasovagal reactions, and ventricular arrhythmias, as well as drugs for narcotic or benzodiazepine reversal, and protamine if heparin is administered. Resuscitation equipment should be monitored and checked routinely in compliance with institutional policies.

VII. RADIATION SAFETY IN IMAGING

Radiologists, medical physicists, non-physician radiology providers, radiologic technologists, and all supervising physicians have a responsibility for safety in the workplace by keeping radiation exposure to staff, and to society as a whole, "as low as reasonably achievable" (ALARA) and to assure that radiation doses to individual patients are appropriate, taking into account the possible risk from radiation exposure and the diagnostic image quality necessary to achieve the clinical objective. All personnel who work with ionizing radiation must understand the key principles of occupational and public radiation protection (justification, optimization of protection, application of dose constraints and limits) and the principles of proper management of radiation dose to patients (justification, optimization including the use of dose reference levels). https://www-pub.iaea.org/MTCD/Publications/PDF/PUB1775_web.pdf

Nationally developed guidelines, such as the ACR's Appropriateness Criteria®, should be used to help choose the most appropriate imaging procedures to prevent unnecessary radiation exposure.

Facilities should have and adhere to policies and procedures that require ionizing radiation examination protocols (radiography, fluoroscopy, interventional radiology, CT) to vary according to diagnostic requirements and patient body habitus to optimize the relationship between appropriate radiation dose and adequate image quality. Automated dose reduction technologies available on imaging equipment should be used, except when inappropriate for a specific exam. If such technology is not available, appropriate manual techniques should be used.

Additional information regarding patient radiation safety in imaging is available from the following websites – Image Gently® for children (www.imagegently.org) and Image Wisely® for adults (www.imagewisely.org). These advocacy and awareness campaigns provide free educational materials for all stakeholders involved in imaging (patients, technologists, referring providers, medical physicists, and radiologists).

Radiation exposures or other dose indices should be periodically measured by a Qualified Medical Physicist in accordance with the applicable ACR Technical Standards. Monitoring or regular review of dose indices from patient imaging should be performed by comparing the facility's dose information with national benchmarks, such as the ACR Dose Index Registry and relevant publications relying on its data, applicable ACR Practice Parameters, NCRP Report No. 172, Reference Levels and Achievable Doses in Medical and Dental Imaging: Recommendations for the United States or the Conference of Radiation Control Program Director's National Evaluation of X-ray Trends; 2006, 2009, amended 2013, revised 2023 (Res. 2d).

VIII. QUALITY CONTROL AND IMPROVEMENT, SAFETY, INFECTION CONTROL, AND PATIENT EDUCATION

Policies and procedures related to quality, patient education, infection control, and safety should be developed and implemented in accordance with the ACR Policy on Quality Control and Improvement, Safety, Infection Control, and Patient Education appearing under the heading *ACR Position Statement on Quality Control & Improvement, Safety, Infection Control, and Patient Education* on the ACR website (https://www.acr.org/Advocacy-and-Economics/ACR-Position-Statements/Quality-Control-and-Improvement).

IX. QUALITY IMPROVEMENT

Clinical outcomes for endovascular AIS interventions depend on both individual and facility performance. A quality improvement program is necessary to identify performance results and opportunities for improvement to reduce treatment times and improve revascularization rates. This should also include efforts by stroke teams to advance appropriate treatment for all patients as well as efforts to mitigate health disparities for embolectomy and revascularization [72]. A multisociety and multispecialty consensus paper provides indicators and thresholds for performance [53]. Physicians and facilities that provide these stroke interventions should meet these thresholds. These indicators and thresholds are being revised to include the most recent trial results.

The data developed through policies and procedures such as those described in Section VIII should be used to assess diagnostic cervicocerebral catheter angiographic procedural efficacy and complication rates and, as defined in those sections, to trigger institutional review when the thresholds defined in those sections are exceeded.

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REFERENCES

1. Chia NH, Leyden JM, Newbury J, Jannes J, Kleinig TJ. Determining the Number of Ischemic Strokes Potentially Eligible for Endovascular Thrombectomy: A Population-Based Study. Stroke 2016;47:1377-80.
2. Rai AT, Domico JR, Buseman C, et al. A population-based incidence of M2 strokes indicates potential expansion of large vessel occlusions amenable to endovascular therapy. Journal of neurointerventional surgery 2018;10:510-15.
3. Rai AT, Seldon AE, Boo S, et al. A population-based incidence of acute large vessel occlusions and thrombectomy eligible patients indicates significant potential for growth of endovascular stroke therapy in

the USA. Journal of neurointerventional surgery 2017;9:722-26.
4. Benjamin EJ, Blaha MJ, Chiuve SE, et al. Heart Disease and Stroke Statistics-2017 Update: A Report From the American Heart Association. Circulation 2017;135:e146-e603.
5. Girotra T, Lekoubou A, Bishu K, Ovbiagele B. Abstract 73: the true cost of stroke: assessment of direct and indirect cost of stroke among all age groups in United States of America from 2003 to 2014. Stroke 2019;50.
6. Berkhemer OA, Fransen PS, Beumer D, et al. A randomized trial of intraarterial treatment for acute ischemic stroke. The New England journal of medicine 2015;372:11-20.
7. Campbell BC, Mitchell PJ, Kleinig TJ, et al. Endovascular therapy for ischemic stroke with perfusion-imaging selection. The New England journal of medicine 2015;372:1009-18.
8. Goyal M, Demchuk AM, Menon BK, et al. Randomized assessment of rapid endovascular treatment of ischemic stroke. The New England journal of medicine 2015;372:1019-30.
9. Jovin TG, Chamorro A, Cobo E, et al. Thrombectomy within 8 hours after symptom onset in ischemic stroke. The New England journal of medicine 2015;372:2296-306.
10. Saver JL, Goyal M, Bonafe A, et al. Solitaire with the Intention for Thrombectomy as Primary Endovascular Treatment for Acute Ischemic Stroke (SWIFT PRIME) trial: protocol for a randomized, controlled, multicenter study comparing the Solitaire revascularization device with IV tPA with IV tPA alone in acute ischemic stroke. International journal of stroke : official journal of the International Stroke Society 2015;10:439-48.
11. Jovin TG, Saver JL, Ribo M, et al. Diffusion-weighted imaging or computerized tomography perfusion assessment with clinical mismatch in the triage of wake up and late presenting strokes undergoing neurointervention with Trevo (DAWN) trial methods. International journal of stroke : official journal of the International Stroke Society 2017;12:641-52.
12. Nogueira RG, Jadhav AP, Haussen DC, et al. Thrombectomy 6 to 24 Hours after Stroke with a Mismatch between Deficit and Infarct. The New England journal of medicine 2018;378:11-21.
13. Sarraj A, Hassan AE, Abraham MG, et al. Trial of Endovascular Thrombectomy for Large Ischemic Strokes. New England Journal of Medicine 2023;388:1259-71.
14. Huo X, Ma G, Tong X, et al. Trial of Endovascular Therapy for Acute Ischemic Stroke with Large Infarct. New England Journal of Medicine 2023;388:1272-83.
15. Yoshimura S, Sakai N, Yamagami H, et al. Endovascular Therapy for Acute Stroke with a Large Ischemic Region. New England Journal of Medicine 2022;386:1303-13.
16. Jovin TG, Li C, Wu L, et al. Trial of Thrombectomy 6 to 24 Hours after Stroke Due to Basilar-Artery Occlusion. New England Journal of Medicine 2022;387:1373-84.
17. Tao C, Nogueira RG, Zhu Y, et al. Trial of Endovascular Treatment of Acute Basilar-Artery Occlusion. New England Journal of Medicine 2022;387:1361-72.
18. Goyal N, Tsivgoulis G, Frei D, et al. A multicenter study of the safety and effectiveness of mechanical thrombectomy for patients with acute ischemic stroke not meeting top-tier evidence criteria. Journal of neurointerventional surgery 2017.
19. Broderick JP, Palesch YY, Demchuk AM, et al. Endovascular therapy after intravenous t-PA versus t-PA alone for stroke. The New England journal of medicine 2013;368:893-903.
20. Kidwell CS, Jahan R, Gornbein J, et al. A trial of imaging selection and endovascular treatment for ischemic stroke. The New England journal of medicine 2013;368:914-23.
21. Haussen DC, Bouslama M, Grossberg JA, et al. Too good to intervene? Thrombectomy for large vessel occlusion strokes with minimal symptoms: an intention-to-treat analysis. Journal of neurointerventional surgery 2016.
22. Powers W, Rabinstein A, Ackerson T, et al. Guidelines for the early management of patients with acute ischemic stroke: 2019 update to the 2018 guidelines for the early management of acute ischemic stroke. A guideline for healthcare professionals from the American Heart Association/American Stroke Association. Stroke 2019;50:e344-e418.
23. Madaelil TP, Kansagra AP, Cross DT, Moran CJ, Derdeyn CP. Mechanical thrombectomy in pediatric acute ischemic stroke: Clinical outcomes and literature review. Interventional neuroradiology : journal of peritherapeutic neuroradiology, surgical procedures and related neurosciences 2016;22:426-31.
24. Goyal M, Menon BK, van Zwam WH, et al. Endovascular thrombectomy after large-vessel ischaemic stroke: a meta-analysis of individual patient data from five randomised trials. Lancet 2016;387:1723-31.
25. Lansberg MG, Mlynash M, Hamilton S, et al. Association of Thrombectomy With Stroke Outcomes Among

Patient Subgroups: Secondary Analyses of the DEFUSE 3 Randomized Clinical Trial. JAMA neurology 2019;76:447-53.
26. Meyer L, Alexandrou M, Flottmann F, et al. Endovascular Treatment of Very Elderly Patients Aged =90 With Acute Ischemic Stroke. J Am Heart Assoc 2020;9:e014447.
27. Saver JL, Goyal M, van der Lugt A, et al. Time to Treatment With Endovascular Thrombectomy and Outcomes From Ischemic Stroke: A Meta-analysis. Jama 2016;316:1279-88.
28. Albers GW, Marks MP, Kemp S, et al. Thrombectomy for Stroke at 6 to 16 Hours with Selection by Perfusion Imaging. The New England journal of medicine 2018;378:708-18.
29. Desai SM, Haussen DC, Aghaebrahim A, et al. Thrombectomy 24 hours after stroke: beyond DAWN. Journal of neurointerventional surgery 2018;10:1039-42.
30. Furlan A, Higashida R, Wechsler L, et al. Intra-arterial prourokinase for acute ischemic stroke. The PROACT II study: a randomized controlled trial. Prolyse in Acute Cerebral Thromboembolism. Jama 1999;282:2003-11.
31. Wintermark M, Luby M, Bornstein NM, et al. International survey of acute stroke imaging used to make revascularization treatment decisions. International journal of stroke : official journal of the International Stroke Society 2015;10:759-62.
32. Kamal N, Holodinsky JK, Stephenson C, et al. Improving Door-to-Needle Times for Acute Ischemic Stroke: Effect of Rapid Patient Registration, Moving Directly to Computed Tomography, and Giving Alteplase at the Computed Tomography Scanner. Circ Cardiovasc Qual Outcomes 2017;10.
33. Noorian AR, Rangaraju S, Sun CH, et al. Endovascular Therapy in Strokes with ASPECTS 5-7 May Result in Smaller Infarcts and Better Outcomes as Compared to Medical Treatment Alone. Interventional neurology 2015;4:30-7.
34. Rebello LC, Bouslama M, Haussen DC, et al. Endovascular Treatment for Patients With Acute Stroke Who Have a Large Ischemic Core and Large Mismatch Imaging Profile. JAMA neurology 2017;74:34-40.
35. Yoo AJ, Berkhemer OA, Fransen PSS, et al. Effect of baseline Alberta Stroke Program Early CT Score on safety and efficacy of intra-arterial treatment: a subgroup analysis of a randomised phase 3 trial (MR CLEAN). The Lancet. Neurology 2016;15:685-94.
36. Bala F, Kim BJ, Najm M, et al. Outcomes with Endovascular Treatment of Patients with M2 Segment MCA Occlusion in the Late Time Window. AJNR. American journal of neuroradiology 2023;44:447-52.
37. Jayaraman MV, Hussain MS, Abruzzo T, et al. Embolectomy for stroke with emergent large vessel occlusion (ELVO): report of the Standards and Guidelines Committee of the Society of NeuroInterventional Surgery. Journal of neurointerventional surgery 2015;7:316-21.
38. Lyden P. Using the National Institutes of Health Stroke Scale: A Cautionary Tale. Stroke 2017;48:513-19.
39. Liebeskind DS, Bracard S, Guillemin F, et al. eTICI reperfusion: defining success in endovascular stroke therapy. Journal of neurointerventional surgery 2019;11:433-38.
40. Saver JL, Goyal M, Bonafe A, et al. Stent-retriever thrombectomy after intravenous t-PA vs. t-PA alone in stroke. The New England journal of medicine 2015;372:2285-95.
41. Lemmens R, Hamilton SA, Liebeskind DS, et al. Effect of endovascular reperfusion in relation to site of arterial occlusion. Neurology 2016;86:762-70.
42. Coutinho JM, Liebeskind DS, Slater LA, et al. Mechanical Thrombectomy for Isolated M2 Occlusions: A Post Hoc Analysis of the STAR, SWIFT, and SWIFT PRIME Studies. AJNR. American journal of neuroradiology 2016;37:667-72.
43. Sarraj A, Sangha N, Hussain MS, et al. Endovascular Therapy for Acute Ischemic Stroke With Occlusion of the Middle Cerebral Artery M2 Segment. JAMA neurology 2016;73:1291-96.
44. Sheth SA, Yoo B, Saver JL, et al. M2 occlusions as targets for endovascular therapy: comprehensive analysis of diffusion/perfusion MRI, angiography, and clinical outcomes. Journal of neurointerventional surgery 2015;7:478-83.
45. Tomsick TA, Carrozzella J, Foster L, et al. Endovascular Therapy of M2 Occlusion in IMS III: Role of M2 Segment Definition and Location on Clinical and Revascularization Outcomes. AJNR. American journal of neuroradiology 2017;38:84-89.
46. Menon BK, Hill MD, Davalos A, et al. Efficacy of endovascular thrombectomy in patients with M2 segment middle cerebral artery occlusions: meta-analysis of data from the HERMES Collaboration. Journal of neurointerventional surgery 2019;11:1065-69.
47. Turc G, Bhogal P, Fischer U, et al. European Stroke Organisation (ESO) - European Society for Minimally Invasive Neurological Therapy (ESMINT) Guidelines on Mechanical Thrombectomy in Acute Ischemic Stroke.

Journal of neurointerventional surgery 2019.
48. Liu X, Dai Q, Ye R, et al. Endovascular treatment versus standard medical treatment for vertebrobasilar artery occlusion (BEST): an open-label, randomised controlled trial. The Lancet. Neurology 2020;19:115-22.
49. Langezaal LCM, van der Hoeven E, Mont'Alverne FJA, et al. Endovascular Therapy for Stroke Due to Basilar-Artery Occlusion. The New England journal of medicine 2021;384:1910-20.
50. Alemseged F, Nguyen TN, Alverne FM, Liu X, Schonewille WJ, Nogueira RG. Endovascular Therapy for Basilar Artery Occlusion. Stroke 2023;54:1127-37.
51. American College of Radiology. ACR–SPR Practice Parameter for Imaging Pregnant or Potentially Pregnant Adolescents and Women With Ionizing Radiation. Available at: https://www.acr.org/-/media/ACR/Files/Practice-Parameters/Pregnant-Pts.pdf?la=en. Accessed January 29, 2023.
52. American College of Radiology. ACR–ASNR–SIR–SNIS Practice Parameter for the Performance of Diagnostic Cervicocerebral Catheter Angiography in Adults. Available at: https://www.acr.org/-/media/ACR/Files/Practice-Parameters/CervicoCerebralCathAngio.pdf?la=en. Accessed January 26, 2023.
53. Sacks D, Black CM, Cognard C, et al. Multisociety consensus quality improvement guidelines for intraarterial catheter-directed treatment of acute ischemic stroke, from the American Society of Neuroradiology, Canadian Interventional Radiology Association, Cardiovascular and Interventional Radiological Society of Europe, Society for Cardiovascular Angiography and Interventions, Society of Interventional Radiology, Society of NeuroInterventional Surgery, European Society of Minimally Invasive Neurological Therapy, and Society of Vascular and Interventional Neurology. Journal of vascular and interventional radiology : JVIR 2013;24:151-63.
54. Powers WJ, Derdeyn CP, Biller J, et al. 2015 American Heart Association/American Stroke Association Focused Update of the 2013 Guidelines for the Early Management of Patients With Acute Ischemic Stroke Regarding Endovascular Treatment: A Guideline for Healthcare Professionals From the American Heart Association/American Stroke Association. Stroke 2015;46:3020-35.
55. American College of Radiology. ACR Practice Parameter for Continuing Medical Education (CME). Available at: https://www.acr.org/-/media/ACR/Files/Practice-Parameters/CME.pdf?la=en. Accessed January 29, 2023.
56. American College of Radiology. ACR–SIR Practice Parameter for Minimal and/or Moderate Sedation/Analgesia. Available at: https://www.acr.org/-/media/ACR/Files/Practice-Parameters/Sed-Analgesia.pdf?la=en. Accessed January 29, 2023.
57. Ang TE, Bivard A, Levi C, et al. Multi-modal CT in acute stroke: wait for a serum creatinine before giving intravenous contrast? No! International journal of stroke : official journal of the International Stroke Society 2015;10:1014-7.
58. American College of Radiology. ACR–SIR–SPR Practice Parameter on Informed Consent for Image-Guided Procedures. Available at: https://www.acr.org/-/media/ACR/Files/Practice-Parameters/InformedConsent-ImagGuided.pdf?la=en. Accessed January 29, 2023.
59. Campbell D, Butler E, Campbell RB, Ho J, Barber PA. General Anesthesia Compared With Non-GA in Endovascular Thrombectomy for Ischemic Stroke: A Systematic Review and Meta-analysis of Randomized Controlled Trials. Neurology 2023;100:e1655-e63.
60. Talke PO, Sharma D, Heyer EJ, Bergese SD, Blackham KA, Stevens RD. Society for Neuroscience in Anesthesiology and Critical Care Expert consensus statement: anesthetic management of endovascular treatment for acute ischemic stroke*: endorsed by the Society of NeuroInterventional Surgery and the Neurocritical Care Society. Journal of neurosurgical anesthesiology 2014;26:95-108.
61. Bonatti M, Lombardo F, Zamboni GA, et al. Iodine Extravasation Quantification on Dual-Energy CT of the Brain Performed after Mechanical Thrombectomy for Acute Ischemic Stroke Can Predict Hemorrhagic Complications. AJNR. American journal of neuroradiology 2018;39:441-47.
62. Tijssen MP, Hofman PA, Stadler AA, et al. The role of dual energy CT in differentiating between brain haemorrhage and contrast medium after mechanical revascularisation in acute ischaemic stroke. Eur Radiol 2014;24:834-40.
63. Butcher K, Christensen S, Parsons M, et al. Postthrombolysis blood pressure elevation is associated with hemorrhagic transformation. Stroke 2010;41:72-7.
64. Oliveira-Filho J, Silva SC, Trabuco CC, Pedreira BB, Sousa EU, Bacellar A. Detrimental effect of blood pressure reduction in the first 24 hours of acute stroke onset. Neurology 2003;61:1047-51.
65. Wahlgren N, Ahmed N, Davalos A, et al. Thrombolysis with alteplase for acute ischaemic stroke in the Safe

Implementation of Thrombolysis in Stroke-Monitoring Study (SITS-MOST): an observational study. Lancet 2007;369:275-82.
66. Mandzia JL, Hill MD. Acute stroke management in patients with known or suspected atrial fibrillation. The Canadian journal of cardiology 2013;29:S45-53.
67. Fuentes B, Castillo J, San Jose B, et al. The prognostic value of capillary glucose levels in acute stroke: the GLycemia in Acute Stroke (GLIAS) study. Stroke 2009;40:562-8.
68. De Georgia M, Patel V. Critical care management in acute ischemic stroke. Journal of neurointerventional surgery 2011;3:34-7.
69. Kramer AH, Zygun DA. Anemia and red blood cell transfusion in neurocritical care. Crit Care 2009;13:R89.
70. Carvalho H, Wessell A, Cannarsa G, Miller T, Gandhi D, Jindal G. E-053 Peri-procedure anemia is associated with poor functional outcome after mechanical thrombectomy for acute ischemic stroke: single center experience. Available at: https://jnis.bmj.com/content/12/Suppl_1/A56.1. Accessed September 8, 2020.
71. American College of Radiology. ACR–SIR–SPR Practice Parameter for the Reporting and Archiving of Interventional Radiology Procedures. Available at: https://www.acr.org/-/media/ACR/Files/Practice-Parameters/Reporting-Archiv.pdf?la=en. Accessed January 29, 2023.
72. Brinjikji W, Rabinstein AA, McDonald JS, Cloft HJ. Socioeconomic disparities in the utilization of mechanical thrombectomy for acute ischemic stroke in US hospitals. AJNR. American journal of neuroradiology 2014;35:553-6.
73. Barber PA, Demchuk AM, Zhang J, Buchan AM. Validity and reliability of a quantitative computed tomography score in predicting outcome of hyperacute stroke before thrombolytic therapy. ASPECTS Study Group. Alberta Stroke Programme Early CT Score. Lancet 2000;355:1670-4.
74. Barber PA, Hill MD, Eliasziw M, et al. Imaging of the brain in acute ischaemic stroke: comparison of computed tomography and magnetic resonance diffusion-weighted imaging. Journal of neurology, neurosurgery, and psychiatry 2005;76:1528-33.
75. Finlayson O, John V, Yeung R, et al. Interobserver agreement of ASPECT score distribution for noncontrast CT, CT angiography, and CT perfusion in acute stroke. Stroke 2013;44:234-6.
76. Kosior RK, Lauzon ML, Steffenhagen N, Kosior JC, Demchuk A, Frayne R. Atlas-based topographical scoring for magnetic resonance imaging of acute stroke. Stroke 2010;41:455-60.
77. Nezu T, Koga M, Nakagawara J, et al. Early ischemic change on CT versus diffusion-weighted imaging for patients with stroke receiving intravenous recombinant tissue-type plasminogen activator therapy: stroke acute management with urgent risk-factor assessment and improvement (SAMURAI) rt-PA registry. Stroke 2011;42:2196-200.
78. Kernan WN, Ovbiagele B, Black HR, et al. Guidelines for the prevention of stroke in patients with stroke and transient ischemic attack: a guideline for healthcare professionals from the American Heart Association/American Stroke Association. Stroke 2014;45:2160-236.
79. Easton JD, Saver JL, Albers GW, et al. Definition and evaluation of transient ischemic attack: a scientific statement for healthcare professionals from the American Heart Association/American Stroke Association Stroke Council; Council on Cardiovascular Surgery and Anesthesia; Council on Cardiovascular Radiology and Intervention; Council on Cardiovascular Nursing; and the Interdisciplinary Council on Peripheral Vascular Disease. The American Academy of Neurology affirms the value of this statement as an educational tool for neurologists. Stroke 2009;40:2276-93.
80. Sacco RL, Kasner SE, Broderick JP, et al. An updated definition of stroke for the 21st century: a statement for healthcare professionals from the American Heart Association/American Stroke Association. Stroke 2013;44:2064-89.
81. Tung EL, McTaggart RA, Baird GL, et al. Rethinking Thrombolysis in Cerebral Infarction 2b: Which Thrombolysis in Cerebral Infarction Scales Best Define Near Complete Recanalization in the Modern Thrombectomy Era? Stroke 2017;48:2488-93.
82. Zaidat OO, Yoo AJ, Khatri P, et al. Recommendations on angiographic revascularization grading standards for acute ischemic stroke: a consensus statement. Stroke 2013;44:2650-63.
83. Schaefer PW, Yoo AJ, Bell D, et al. CT angiography-source image hypoattenuation predicts clinical outcome in posterior circulation strokes treated with intra-arterial therapy. Stroke 2008;39:3107-9.
84. Puetz V, Sylaja PN, Coutts SB, et al. Extent of hypoattenuation on CT angiography source images predicts functional outcome in patients with basilar artery occlusion. Stroke 2008;39:2485-90.
85. Nagel S, Herweh C, Köhrmann M, et al. MRI in patients with acute basilar artery occlusion - DWI lesion

scoring is an independent predictor of outcome. International journal of stroke : official journal of the International Stroke Society 2012;7:282-8.

86. National Institutes of Health. NIH Stroke Scale. Available at: https://www.ninds.nih.gov/health-information/public-education/know-stroke/health-professionals/nih-stroke-scale. Accessed January 8, 2024.
87. Rennert RC, Wali AR, Steinberg JA, et al. Epidemiology, Natural History, and Clinical Presentation of Large Vessel Ischemic Stroke. *Neurosurgery*. 2019;85(suppl_1):S4-S8. doi:10.1093/neuros/nyz042.
88. Powers WJ, Rabinstein AA, Ackerson T, et al. 2018 Guidelines for the Early Management of Patients With Acute Ischemic Stroke: A Guideline for Healthcare Professionals From the American Heart Association/American Stroke Association [published correction appears in Stroke. 2018 Mar;49(3):e138] [published correction appears in Stroke. 2018 Apr 18;:]. *Stroke*. 2018;49(3):e46-e110. doi:10.1161/STR.0000000000000158.
89. Powers WJ, Rabinstein AA, Ackerson T, et al. Guidelines for the Early Management of Patients With Acute Ischemic Stroke: 2019 Update to the 2018 Guidelines for the Early Management of Acute Ischemic Stroke: A Guideline for Healthcare Professionals From the American Heart Association/American Stroke Association [published correction appears in Stroke. 2019 Dec;50(12):e440-e441]. *Stroke*. 2019;50(12):e344-e418. doi:10.1161/STR.0000000000000211.
90. Hoh BL, Ko NU, Amin-Hanjani S, et al. 2023 Guideline for the Management of Patients With Aneurysmal Subarachnoid Hemorrhage: A Guideline From the American Heart Association/American Stroke Association [published correction appears in Stroke. 2023 Dec;54(12):e516]. *Stroke*. 2023;54(7):e314-e370. doi:10.1161/STR.0000000000000436.
91. Kobeissi H, Ghozy S, Adusumilli G, et al. Endovascular Therapy for Stroke Presenting Beyond 24 Hours: A Systematic Review and Meta-analysis. *JAMA Netw Open*. 2023;6(5):e2311768. Published 2023 May 1. doi:10.1001/jamanetworkopen.2023.11768.
92. Dhillon PS, Butt W, Podlasek A, et al. Endovascular thrombectomy beyond 24 hours from ischemic stroke onset: a propensity score matched cohort study. *J Neurointerv Surg*. 2023;15(3):233-237. doi:10.1136/neurintsurg-2021-018591.
93. Alawieh A, Chatterjee A, Feng W, et al. Thrombectomy for acute ischemic stroke in the elderly: a 'real world' experience. *J Neurointerv Surg*. 2018;10(12):1209-1217. doi:10.1136/neurintsurg-2018-013787
94. Sabben C, Charbonneau F, Delvoye F, et al. Endovascular Therapy or Medical Management Alone for Isolated Posterior Cerebral Artery Occlusion: A Multicenter Study. *Stroke*. 2023;54(4):928-937. doi:10.1161/STROKEAHA.122.042283
95. Sang H, Li F, Yuan J, et al. Values of Baseline Posterior Circulation Acute Stroke Prognosis Early Computed Tomography Score for Treatment Decision of Acute Basilar Artery Occlusion. *Stroke*. 2021;52(3):811-820. doi:10.1161/STROKEAHA.120.031371
96. Baik SH, Kim JY, Jung C. A Review of Endovascular Treatment for Posterior Circulation Strokes. Neurointervention. 2023 Jun;18(2):90-106. doi: 10.5469/neuroint.2023.00213. Epub 2023 Jun 27. PMID: 37365755; PMCID: PMC10318221.
97. Liu L, Wang M, Deng Y, et al. Novel Diffusion-Weighted Imaging Score Showed Good Prognostic Value for Acute Basilar Artery Occlusion Following Endovascular Treatment: The Pons-Midbrain and Thalamus Score. *Stroke*. 2021;52(12):3989-3997. doi:10.1161/STROKEAHA.120.032314
98. Mourand I, Machi P, Nogué E, et al. Diffusion-weighted imaging score of the brain stem: A predictor of outcome in acute basilar artery occlusion treated with the Solitaire FR device. *AJNR Am J Neuroradiol*. 2014;35(6):1117-1123. doi:10.3174/ajnr.A3870
99. Milburn JM, Fiorella D, Hirsch JA. Betwixt and between: an idiomatic understanding of anesthesia in stroke intervention. *J Neurointerv Surg*. 2023;15(5):411-412. doi:10.1136/jnis-2023-020364
100. National Institutes of Health. Modified Rankin Scale. Available at: https://www.commondataelements.ninds.nih.gov/report-viewer/24953/Modified%20Rankin%20Scale%20(mRS). Accessed January 16, 2024.
101. Banks JL, Marotta CA. Outcomes validity and reliability of the modified Rankin scale: implications for stroke clinical trials: a literature review and synthesis. *Stroke*. 2007;38(3):1091-1096. doi:10.1161/01.STR.0000258355.23810.c6
102. Huo X, Ma G, Tong X, Zhang X, Pan Y, Nguyen TN, Yuan G, Han H, Chen W, Wei M, et al. Trial of endovascular therapy for acute ischemic stroke with large infarct. N Engl J Med. 2023;388:1272-1283.

https://doi.org/ 10.1056/NEJMoa2213379
103. Sarraj A, Hassan AE, Abraham MG, Ortega-Gutierrez S, Kasner SE, Hussain MS, Chen M, Blackburn S, Sitton CW, Churilov L, et al. Trial of endovascular thrombectomy for large ischemic strokes. N Engl J Med. 2023;388:1259-1271. https://doi.org/10.1056/NEJMoa2214403
104. Yoshimura S, Sakai N, Yamagami H, Uchida K, Beppu M, Toyoda K, Matsumaru Y, Matsumoto Y, Kimura K, Takeuchi M, et al. Endovascu- lar therapy for acute stroke with a large ischemic region. N Engl J Med. 2022;386:1303-1313. https://doi.org/10.1056/NEJMoa2118191
105. Yoo A, Zaidat O, Al Kasab S, Sheth S, Rai A, Ortega-Gutierrez S, Given Ii C, Zaidi S, Grandhi R, Cuellar-Saenz HH, et al. O315/3106 thrombec- tomy for emergent salvage of large anterior circulation ischemic storke. In: ESOC 2023. European Stroke Journal; 2023:3-752.
106. Bendszus M, Fiehler J, Subtil F, Bonekamp S, Aamodt AH, Fuentes B, Gizewski ER, Hill MD, Krajina A, Pierot L, et al. Endovascular thrombec- tomy for acute ischaemic stroke with established large infarct: multicen- tre, open-label, randomised trial. Lancet. 2023;402:1753-1763. https://doi.org/10.1016/S0140-6736(23)02032-9

Appendix A

For the purpose of this practice parameter, the following definitions apply:

ASPECTS – A method of measuring early ischemic change, originally described with noncontrast CT [73] and subsequently applied to other CT modalities and to MRI [74-77], which predicts functional outcome and hemorrhage risk in patients who are candidates for intravenous thrombolysis and thrombectomy.

Class of recommendation – A Class 1 recommendation represents a strong recommendation or indication, for which there is evidence for and/or general agreement that the procedure or treatment is useful and effective. A Class 2a recommendation represents a moderate level of recommendation, in which a course of action is considered reasonable or may be useful or beneficial. The weight of evidence or opinion is in favor of the procedure or treatment. A Class 2b recommendation represents a weaker recommendation, in which a course of action might be reasonable, may be considered, or where the usefulness/effectiveness is considered uncertain or less well established by evidence or opinion. A Class 3 recommendation represents a course of action for which there is evidence and/or general agreement that the procedure or treatment is not useful/effective, and in some cases may be harmful [22,78].

Central nervous system (CNS) infarction – CNS infarction is brain, spinal cord, or retinal cell death attributable to ischemia, based on pathological, imaging, other objective evidence of cerebral, spinal cord, or retinal focal ischemic injury in a defined vascular distribution, or clinical evidence of cerebral, spinal cord, or retinal focal ischemic injury based on symptoms persisting >24 hours or until death, and other etiologies excluded (Note: CNS infarction includes hemorrhagic infarctions (HI), types I and II; see "HI" [22,78-80]).

Diagnostic catheter angiography – a minimally invasive procedure involving percutaneous catheterization of any of the arteries or veins involving the head and neck, brain, or spinal cord, performed with injection of a radiocontrast agent and digital subtraction imaging.

ELVO – Any acute occlusion of the internal carotid, proximal anterior cerebral, proximal middle cerebral (M1 and M2 segments), proximal posterior cerebral, or vertebrobasilar arteries documented by vascular imaging [37].

HI – Type I is defined by petechiae of blood along the margins of the infarction, whereas Type II has confluent petechiae within the infarction but without a space-occupying effect. HI is characterized by its lack of mass effect [80].

Intracerebral hemorrhage (ICH) – A focal collection of blood within the brain parenchyma or ventricular system that is not caused by trauma (Note: ICH includes parenchymal hemorrhages after CNS infarction; see "HI" and "Parenchymal Infarction" [80].)

Ischemic stroke – An episode of neurological dysfunction caused by focal cerebral, spinal, or retinal infarction (Note: Evidence of CNS infarction is as defined previously [22,78-80].)

Level of evidence – Level A evidence is high-level evidence, most often derived from more than one randomized controlled trial, a meta-analysis of high-quality randomized controlled trials, or a randomized controlled trial supported by a high-quality registry. Level B evidence is moderate-quality evidence, which may be derived from randomized controlled trials or a well-designed nonrandomized study, or a meta-analysis of such trials. Level C evidence is considered limited- or lower-level evidence, based on observational trials or registries, meta-analyses of such trials, or consensus of expert opinion based on experience [22,78].

Major complication – An event that results in admission to the hospital for therapy (for outpatient procedures), an unplanned increase in the level of care, an unplanned increase in the length of hospital stay, or in permanent adverse sequelae or death (for further information, see the Proposal of a New Adverse Event Classification by the Society of Interventional Radiology Standards of Practice Committee).

Mechanical thrombectomy – A minimally invasive procedure involving diagnostic catheter angiography followed by direct removal of a thromboembolus from a target vessel using catheter-based techniques. Examples may involve use of a stent retriever or an aspiration device, with or without maceration of the clot.

Minor complication – An event that results in no sequelae or requires minimal therapy or a short hospital stay for observation (for further information, see the Proposal of a New Adverse Event Classification by the Society of Interventional Radiology Standards of Practice Committee).

mRS – A 7-point ordinal scale for measuring the degree of disability or dependence of patients who have suffered a stroke. It is a measure of overall functional outcome, rather than specific symptom severity. The scale ranges from 0 (no symptoms) to 6 (dead) [100,101].

Modified thrombolysis in cerebral infarction (mTICI) or expanded thrombolysis in cerebral infarction (eTICI) *score – A scale ranging from 0 to 3 that describes the degree of (re)perfusion of an artery past its initial occlusion and into its distal branches. A score of 0 indicates no perfusion, whereas a score of 3 indicates full reperfusion with filling of all the distal branches, including M3 and M4 [81].*

NIHSS – A 42-point scale used to objectively and reproducibly quantify the severity of select symptoms caused by a stroke. The NIHSS is composed of 11 items, each of which scores a specific area of neurological function from 0 (not present) up to 4 (most severe). In the case of coma, certain scores (eg, those for ataxia) default to 0, so the maximum score in a comatose patient is 39 [38,86]. Other stroke evaluation scales are published [39,81,82].

Parenchymal hemorrhage (PH) – Type I is a confluent hemorrhage limited to <30% of the infarcted area with only mild space-occupying effect, and Type II is >30% of the infarcted area and/or exerts a significant space-occupying effect. PH is characterized by the presence of mass effect, similar to the ICH definition of a focal collection of blood. PH should be considered ICHs [80].

Pons-midbrain Index – An 8-point scale to score ischemic changes in the pons and midbrain. A score of 0 is no ischemic changes. A score of 8 is ischemia in more than 50% of both the right and left halves of the pons and midbrain. It is applied to CTA source images and diffusion weighted MR images. It correlates with clinical outcome in patients with vertebrobasilar artery occlusion treated with reperfusion therapy [83].

pc-ASPECTS – A method of measuring early ischemic change for posterior circulation strokes. It was first described for noncontrast CT brain and CTA source images [84] and subsequently MRI [85]. It may help identify patients with BAO who are unlikely to benefit from reperfusion therapy.

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Stent retriever – A stent-like device that is used to remove a thromboembolus from an occluded vessel.

Stroke caused by ICH – Rapidly developing clinical signs of neurological dysfunction attributable to a focal collection of blood within the brain parenchyma or ventricular system that is not caused by trauma [80].

Subarachnoid hemorrhage – Bleeding into the subarachnoid space (the space between the arachnoid membrane and the pia matter of the brain or spinal cord) [80].

Threshold – A specific level of an indicator that should prompt the performance of a review.

Thrombolysis – A method of dissolving a thromboembolus within an occluded vessel using a fibrinolytic medication, such as alteplase. At this time, alteplase is the only FDA-approved medication for use for patients with acute stroke and is only FDA-approved for IV use within 3 hours from time of onset or last known well. Per AHA/ASA guidelines, IV alteplase may be used up to 4.5 hours from onset or last known well in select, eligible patients. The intra-arterial administration of thrombolytics is well described, though considered "off-label" for acute stroke patients [78].

*Practice parameters and technical standards are published annually with an effective date of October 1 in the year in which amended, revised or approved by the ACR Council. For practice parameters and technical standards published before 1999, the effective date was January 1 following the year in which the practice parameter or technical standard was amended, revised, or approved by the ACR Council.

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