

# Provider Led Entity

## CDI Quality Institute PLE Stroke AUC

07/31/2018

### Appropriateness of advanced imaging procedures\* in patients with stroke/cerebrovascular accident (CVA) and the following clinical presentations or diagnoses:

\*Including MRI, MR angiography, MR venography, MR perfusion, CT, CT angiography, CT venography, CT perfusion, nuclear medicine, SPECT, PET, PET/CT

Abbreviation list:

ACEP	American College of Emergency Physicians	GCS	Glasgow Coma Scale
ACR	American College of Radiology	ICA	Internal carotid artery
AHA	American Heart Association	ICH	Intracranial hemorrhage
AIS	Acute ischemic stroke	LVO	Large vessel occlusion
ASA	American Stroke Association	MCA	Middle cerebral artery
AUC	Appropriate Use Criteria	MRA	Magnetic resonance angiography
CAS	Carotid angioplasty and stenting	MRI	Magnetic resonance imaging
CEA	Carotid endarterectomy	MRP	MR perfusion
CT	Computed tomography	MRV	MR venography
CTA	Computed tomographic angiography	NASCET	North American Symptomatic Carotid Endarterectomy Trial
CTP	CT perfusion	NCCT	Noncontrast CT
CTV	CT venography	NICE	National Institute for Health and Care Excellence
CVA	Cerebrovascular accident	PET	Positron emission tomography
CVST	Cerebral venous sinus thrombosis	PLE	Provider Led Entity
DWI	Diffusion weighted imaging	SIGN	Scottish Intercollegiate Guidelines Network
ECST	European Carotid Surgery Trial	SNIL	Silent new ischemic lesion
ECVD	Extracranial Carotid and Vertebral Artery Disease	TIA	Transient ischemic attack
ESVS	European Society for Vascular Surgery	tPA	Tissue plasminogen activator
ESO	European Stroke Organization	US	Ultrasound
		USPSTF	U.S. Preventive Services Task Force

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## Physical findings, radiographic signs, or risk factors suggestive of carotid artery stenosis in an asymptomatic patient<sup>†</sup>:

- **Green** – \*
- **Yellow** – MRA neck with contrast to further characterize hemodynamically significant carotid artery stenosis detected or suspected on duplex carotid ultrasound
- **Yellow** – CTA neck to further characterize hemodynamically significant carotid artery stenosis detected or suspected on duplex carotid ultrasound
- **Yellow** – MRA neck with contrast in patients with an indeterminate or nondiagnostic duplex carotid ultrasound or when ultrasound is not available
- **Yellow** – CTA neck in patients with an indeterminate or nondiagnostic duplex carotid ultrasound or when ultrasound is not available
- **Yellow** – MRA neck without contrast in patients with an indeterminate or nondiagnostic duplex carotid ultrasound, when ultrasound is not available, or to further characterize hemodynamically significant carotid artery stenosis detected or suspected on duplex carotid ultrasound in patients unable to receive MRI or CT contrast
- **Yellow** – MRA head without contrast in patients with established carotid artery stenosis being evaluated for carotid stenting
- **Yellow** – CTA head in patients with established carotid artery stenosis being evaluated for carotid stenting
- **Yellow** – MRA head with contrast in patients with established carotid artery stenosis being evaluated for carotid stenting and a nondiagnostic or inconclusive MRA head without contrast
- **Red** – CT head with and/or without contrast; MRI brain with and/or without contrast; CT perfusion; MR perfusion; CT venography; MR venography

<sup>†</sup>Screening for asymptomatic carotid artery disease is not recommended in the general adult population without signs, symptoms or risk factors.

\* Duplex carotid ultrasound is indicated for the initial evaluation of asymptomatic patients at high risk for, with signs of, or with radiographic evidence of carotid artery stenosis.

Level of Evidence: CTA neck with contrast, MRA neck without and with contrast, MRA neck without contrast: n/a

Notes concerning applicability and/or patient preferences: none

### Guideline and PLE expert panel consensus summary:

The USPSTF recommends against screening for asymptomatic carotid artery stenosis (CAS) in the general adult population (LeFevre [USPSTF] 2014, D recommendation).

Carotid duplex ultrasonography is not recommended for routine screening of asymptomatic patients who have no clinical manifestations of or risk factors for atherosclerosis (Brott et al. 2011, Class III: No Benefit/Level of Evidence: C; Naylor et al. [ESVS] 2018, Class III/Level of Evidence: B).

Routine serial imaging of the extracranial carotid arteries is not recommended for patients who have no risk factors for development of atherosclerotic carotid disease and no disease evidence on initial vascular testing (Brott et al. 2011, Class III: No Benefit/Level of Evidence: C).

In asymptomatic patients with known or suspected carotid stenosis, duplex ultrasonography, performed by a qualified technologist in a certified laboratory, is recommended as the initial diagnostic test to detect hemodynamically significant carotid stenosis (Brott et al. 2011, Class I/Level of Evidence: C).

Duplex ultrasonography might be considered to detect carotid stenosis in asymptomatic patients without clinical evidence of atherosclerosis who have 2 or more of the following *risk factors*: hypertension, hyperlipidemia, tobacco smoking, a family history in a first-degree relative of atherosclerosis manifested < age 60 years, or a family history of ischemic stroke (Brott et al. 2011, Class IIb/Level of Evidence: C).

Selective screening for asymptomatic carotid stenosis may be considered in patients with multiple vascular *risk factors* to optimize risk factor control and medical therapy to reduce late cardiovascular morbidity and mortality, rather than for identifying candidates for invasive carotid interventions (Naylor et al. [ESVS] 2018, Class IIb/Level of Evidence: C).

Duplex ultrasonography to detect hemodynamically significant carotid stenosis may be considered in asymptomatic patients with symptomatic [peripheral arterial disease] PAD, coronary artery disease (CAD), or atherosclerotic aortic aneurysm, but because such patients already have an indication for medical therapy to prevent ischemic symptoms, it is unclear whether establishing the additional diagnosis of ECVD in those without carotid bruit would justify actions that affect clinical outcomes (Brott et al. 2011, Class IIb/Level of Evidence: C).

It is reasonable to perform duplex ultrasonography to detect hemodynamically significant carotid stenosis in asymptomatic patients with *carotid bruit* (Brott et al. 2011, Class IIa/Level of Evidence: C).

Consider carotid imaging when there is a *silent brain infarction* in the carotid territory (Smith et al. [AHA/ASA] 2017).

Consider noninvasive CT or MR angiography when there are large (> 1.0cm) *silent [intracranial] hemorrhages* (Smith et al. [AHA/ASA] 2017).

Duplex ultrasound (as first-line), computed tomographic angiography and/or magnetic resonance angiography are recommended for evaluating the extent and severity of extracranial carotid stenosis (Naylor et al. [ESVS] 2018, Class I/Level of Evidence: A).

When *carotid endarterectomy is being considered*, it is recommended that duplex ultrasound stenosis estimation be corroborated by computed tomographic angiography or magnetic resonance angiography, or by a repeat duplex ultrasound performed by a second operator (Naylor et al. [ESVS] 2018, Class I/Level of Evidence: A).

When *carotid stenting is being considered*, it is recommended that any duplex ultrasound study be followed by computed tomographic angiography or magnetic resonance angiography which will provide additional information on the aortic arch, as well as the extra- and intracranial circulation (Naylor et al. [ESVS] 2018, Class I/Level of Evidence: A).

If *duplex US or MRA neck without IV contrast are positive*, consider follow-up with CTA or contrast-enhanced MRA. The combination of duplex US and CE-MRA is a common choice for carotid artery

evaluation. CE-MRA is superior to noncontrast TOF-MRA because it is less affected by slow and turbulent flow, particularly at the carotid bifurcation (Salmela et al. [ACR] 2016).

In *asymptomatic patients with structural lesion on physical examination (cervical bruit) and/or risk factors*, the *American College of Radiology* recommends US duplex Doppler carotid (8), MRA neck without IV contrast (8), MRA neck without and with IV contrast (8), CTA neck with IV contrast (8), CT head perfusion with IV contrast (5), MRI head perfusion with IV contrast (5), MRI head without IV contrast (5), MRI head without and with IV contrast (5), and CT head without IV contrast (5) (Salmela et al. [ACR] 2016).

#### Clinical notes:

- Carotid artery disease is responsible for 10%-20% of strokes (Salmela et al. [ACR] 2016; Brott et al. 2011).
- The major risk factors for carotid artery stenosis include older age, male sex, hypertension, smoking, hypercholesterolemia, diabetes mellitus, and heart disease (LeFevre [USPSTF] 2014).
- Calculated age-adjusted incidence of stroke in patients with cervical bruits is 2.6 times that of those without bruits (e.g., Wolf et al. 1981).
- Duplex US is operator dependent and can have difficulty with artifact due to calcified plaque and is limited in the evaluation of near occlusion, tandem lesions, and lesions at the distal carotid and carotid origin (Salmela et al. [ACR] 2016).
- Although MRA has slightly higher sensitivity and specificity than US to determine carotid stenosis and occlusion, the usefulness of either procedure may be determined by other factors, such as availability. Computed tomography angiography (CTA) has a sensitivity and specificity similar to MRA for carotid occlusion and similar to US for the detection of severe stenosis (Irimia et al. 2010, Class II/Level B).
- The advantage of computed tomographic angiography (CTA) and MR angiography (MRA) is the ability to simultaneously image the aortic arch, supra-aortic trunks, carotid bifurcation, distal ICA, and the intracranial circulation, which is mandatory if a patient is being considered for carotid artery stenting (CAS) (Naylor et al. [ESVS] 2018).
- It is reasonable to repeat duplex ultrasonography annually by a qualified technologist to assess the progression or regression of disease and response to therapeutic interventions in patients with atherosclerosis who have had stenosis > 50% detected previously. Once stability has been established over an extended period or the patient's candidacy for further intervention has changed, longer intervals or termination of surveillance may be appropriate (Brott et al. 2011, Class IIa/Level of Evidence: C).
- Duplex US surveillance enables monitoring of disease progression in the contralateral ICA, which is more common than ipsilateral restenosis, with progression being dependent on disease severity at the time of CEA. The data are, however, conflicting as to its benefit (Naylor et al. [ESVS] 2018).

#### Technical notes:

- Duplex ultrasound combines 2-dimensional real-time imaging with Doppler [color] flow analysis to evaluate vessels of interest and measure blood flow velocity (Brott et al. 2011).
- Carotid imaging reports should clearly state which criteria (ECST or NASCET) were used when measuring the extent of carotid stenosis (NICE 2008).
- The NASCET and ECST methods both indicate the degree of stenosis as a percentage reduction in vessel diameter. The minimum diameter of the arteries caused by stenosis (which is the

maximum point of blood constriction) is compared to another diameter that represents the normal diameter of the carotid arteries when the patient is healthy. NASCET includes a measurement taken along a point of the internal carotid artery in a healthy area well beyond an area of the bulb that was caused by stenosis. The ECST formula includes the estimated normal lumen diameter at the site of the lesion, based on a visual impression of where the normal artery wall was before development of the stenosis. (*NICE 2008*).

Evidence update (2016-present): There was no new low, moderate or high quality evidence which significantly affect the evidence and recommendations included in the guidelines cited above.

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## Suspected transient ischemic attack(s) (TIA) or amaurosis fugax:

### Carotid imaging:

- **Green** – MRA neck with contrast\*
- **Yellow** – MRA neck without contrast in patients unable to receive MRI contrast\*
- **Yellow** - CTA neck in patients unable to undergo MRI\*†

### Intracranial vascular imaging:

- **Yellow** – MRA head without contrast when an extracranial source of ischemia is not identified or when intervention for significant carotid stenosis detected by carotid duplex ultrasonography is planned
- **Yellow** - CTA head in patients unable to undergo MRI when an extracranial source of ischemia is not identified or when intervention for significant carotid stenosis detected by carotid duplex ultrasonography is planned†
- **Yellow** – MRA head with contrast in patients with prior stenting when an extracranial source of ischemia is not identified or when intervention for significant carotid stenosis detected by carotid duplex ultrasonography is planned
- **Yellow** – MRA head with contrast in patients with a nondiagnostic or inconclusive MRA head without IV contrast when an extracranial source of ischemia is not identified or when intervention for significant carotid stenosis detected by carotid duplex ultrasonography is planned

### Brain imaging:

- **Green** – CT head without contrast
- **Green** – MRI brain without contrast‡
- **Green** – MRI brain without and with contrast‡
- **Yellow** - CT head with contrast or CT head with and without contrast in a patient unable to undergo MRI
- **Yellow** - CT perfusion in a patient unable to undergo MRI
- **Orange** - MR perfusion
- **Red** – CT venography; MR venography

\* Duplex carotid ultrasound is also indicated and accurate for evaluation of the carotid arteries.

†MRA is the preferred imaging modality as CTA requires the use of IV iodinated contrast and exposes the patient to ionizing radiation (Salmela et al. [ACR] 2016)

‡ MRI of the brain should include diffusion-weighted imaging and gradient recalled imaging or susceptibility-weighted imaging (see recommendations in the technical notes).

Level of Evidence: CT head without contrast, MRA neck without contrast: high; MRI brain without contrast: high for diagnostic accuracy/low for management change; CTA neck with contrast, MRA neck without and with contrast: high for carotid imaging/low for any one modality; MRA head without contrast: low; CT perfusion, MR perfusion: very low

Notes concerning applicability and/or patient preferences: none

Guideline and PLE expert panel consensus summary:

### **Carotid imaging –**

The initial evaluation of patients with transient retinal or hemispheric neurological symptoms of possible ischemic origin should include noninvasive imaging for the detection of ECVD (Brott et al. 2011, Class I/Level of Evidence: C).

Duplex ultrasonography is recommended to detect carotid stenosis in patients who develop focal neurological symptoms corresponding to the territory supplied by the left or right internal carotid artery ECVD (Brott et al. 2011, Class I/Level of Evidence: C).

Duplex carotid ultrasonography might be considered for patients with nonspecific neurological symptoms when cerebral ischemia is a plausible cause (Brott et al. 2011, Class IIb/Level of Evidence: C).

Carotid ultrasonography may be used to exclude severe carotid stenosis because it has accuracy similar to that of MRA or CTA (Lo et al. 2016 [ACEP], Level C Recommendation).

In patients with acute, focal ischemic neurological symptoms corresponding to the territory supplied by the left or right internal carotid artery, magnetic resonance angiography (MRA) or computed tomography angiography (CTA) is indicated to detect carotid stenosis when sonography either cannot be obtained or yields equivocal or otherwise nondiagnostic results (Brott et al. 2011, Class I/Level of Evidence: C).

In candidates for revascularization, MRA or CTA can be useful when results of carotid duplex ultrasonography are equivocal or indeterminate (Brott et al. 2011, Class IIa/Level of Evidence: C).

In patients whose symptoms suggest posterior cerebral or cerebellar ischemia, MRA or CTA is recommended rather than ultrasound imaging for evaluation of the vertebral artery (Brott et al. 2011, Class I/Level of Evidence: C).

MRA without contrast is reasonable to assess the extent of disease in patients with symptomatic carotid atherosclerosis and renal insufficiency or extensive vascular calcification (Brott et al. 2011, Class IIa/Level of Evidence: C).

It is reasonable to use MRI systems capable of consistently generating high-quality images while avoiding low-field systems that do not yield diagnostically accurate results (Brott et al. 2011, Class IIa/Level of Evidence: C).

CTA is reasonable for evaluation of patients with clinically suspected significant carotid atherosclerosis who are not suitable candidates for MRA because of claustrophobia, implanted pacemakers, or other incompatible devices (Brott et al. 2011, Class IIa/Level of Evidence: C).

### **Intracranial vascular imaging –**

When an extracranial source of ischemia is not identified in patients with transient retinal or hemispheric neurological symptoms of suspected ischemic origin, CTA, MRA, or selective cerebral angiography can be useful to search for *intracranial vascular disease* (Brott et al. 2011, Class IIa/Level of Evidence: C).

When intervention for significant carotid stenosis detected by carotid duplex ultrasonography is

planned, MRA, CTA, or catheter-based contrast angiography can be useful to evaluate the severity of stenosis and to identify intrathoracic or *intracranial vascular lesions* that are not adequately assessed by duplex ultrasonography (Brott et al. 2011, Class IIa/Level of Evidence: C).

When noninvasive imaging is inconclusive or not feasible because of technical limitations or contraindications in patients with transient retinal or hemispheric neurological symptoms of suspected ischemic origin, or when noninvasive imaging studies yield discordant results, it is reasonable to perform catheter-based contrast angiography to detect and characterize extracranial and/or intracranial cerebrovascular disease (Brott et al. 2011, Class IIa/Level of Evidence: C).

### **Brain imaging –**

When feasible, physicians should obtain MRI with diffusion-weighted imaging or cervical vascular imaging (e.g., carotid ultrasonography, CTA, or MRA) to identify patients at high short-term risk for stroke (Lo et al. [ACEP] 2016, Level C recommendation).

If noncontrast brain MRI is not readily available, it is reasonable for physicians to obtain a noncontrast head CT as part of the initial TIA workup to identify TIA mimics. However, noncontrast head CT should not be used to identify patients at high short-term risk for stroke (Lo et al. [ACEP] 2016, Level C recommendation).

People who have had a suspected TIA who need brain imaging (that is, those in whom vascular territory or pathology is uncertain) should undergo diffusion-weighted MRI except where contraindicated, in which case computed tomography (CT) scanning should be used (NICE 2008).

CTP may play a role to evaluate for ischemia when MRI is contraindicated or cannot be performed. Additionally, CTP has shown some promise in identifying patients who may benefit from therapy outside the accepted treatment window (Salmela et al. [ACR] 2016).

### **Imaging protocols in patients at low risk for stroke –**

In patients with suspected TIA who are at low risk for stroke, immediate CT without contrast can be followed with outpatient extracranial carotid artery imaging and optimal medical management (PLE expert panel consensus opinion).

People who have a suspected TIA who are at a lower risk of stroke (e.g., ABCD2 score < 4) in whom the vascular territory or pathology is uncertain should undergo brain imaging within 1 week of symptom onset (preferably with diffusion-weighted MRI) (NICE 2008).

People who present more than 1 week after their last symptom of TIA has resolved should be managed using the lower-risk pathway (NICE 2008).

In adult patients with suspected TIA without high-risk conditions (abnormal initial head CT result, suspected embolic source, known carotid stenosis, previous large stroke, crescendo TIA), a rapid ED-based diagnostic protocol may be used to evaluate patients at short-term risk for stroke (Lo et al [ACEP] 2016, Level B recommendation). This includes serial clinical examinations, telemetry monitoring, imaging (MRI and vascular imaging), echocardiography as indicated, and neurology and/or cardiology consultation as needed (Lo et al. [ACEP] 2016).

### **Imaging protocols in patients at high risk for stroke –**

In patients with suspected TIA who are at high risk for stroke, immediate CT without contrast can be followed by outpatient carotid imaging, outpatient MRI brain with DWI, and outpatient intracranial vascular imaging (PLE expert panel consensus opinion).

People who have had a suspected TIA who are at high risk of stroke (e.g., ABCD2 score  $\geq 4$  or with crescendo TIA) in whom the vascular territory or pathology is uncertain should undergo urgent brain imaging (e.g., within 24 hours; preferably with diffusion-weighted MRI). (NICE 2008).

#### **ACR recommendations -**

In patients with *single focal neurologic deficit, acute onset, completely resolving*, the American College of Radiology recommends MRI head without and with IV contrast (8), CT head without IV contrast (8), MRI head without IV contrast (7), MRA head and neck without and with IV contrast (7), MRA head and neck without IV contrast (7), CTA head and neck with IV contrast (7), and CT head without and with IV contrast (6) (Wippold et al. [ACR] 2012).

In patients with *carotid territory or vertebrobasilar TIA, initial screening study*, the American College of Radiology recommends MRI head without and with IV contrast (9), MRI head without IV contrast (8), MRA head and neck without IV contrast (8), MRA head and neck without and with IV contrast (8), CT head without IV contrast (8), CTA head and neck with IV contrast (8), US duplex Doppler carotid (5), CT head perfusion with IV contrast (5), and MRI head perfusion with IV contrast (5) (Salmela et al. [ACR] 2016).

#### Clinical notes:

- TIA is conventionally defined as a syndrome of acute neurological dysfunction referable to the distribution of a single brain artery and characterized by symptoms that last < 24 hours (Brott et al. 2011; Salmela et al. [ACR] 2016).
- Patients with carotid territory symptoms include those with (i) hemi-sensory impairment (numbness, paresthesia of face/arm/leg); (ii) hemimotor deficits (weakness of face/arm/leg, or limb clumsiness), and (iii) higher cortical dysfunction (dysphasia/aphasia, visuospatial problems) (Naylor et al. [ESVS] 2018).
- Amaurosis fugax (transient monocular blindness) refers to transient impairment or loss of vision in one eye (Naylor et al. [ESVS] 2018).
- Frequent causes of transient neurological symptoms that can mimic TIA include migraine aura, seizures, syncope, peripheral vestibular disturbance and functional/anxiety disorder (Nadarajan et al. 2014).
- Neurologic studies have shown that approximately one-third of all TIAs have evidence of infarction at presentation (Lo et al. [ACEP] 2016).
- The risk of acute ischemic stroke after TIA ranges from 3.5-10% at 2 days, 5-10% at 7 days, and 9.2-17% at 90 days (Lo et al. [ACEP] 2016). The 10-year risk for suffering a stroke, myocardial infarction, or death in a TIA patient is as high as 43% (e.g., Clark et al. 2003; van Wijk et al. 2005).
- People who have had a suspected TIA should be assessed as soon as possible for their risk of subsequent stroke using a validated scoring system, such as ABCD2 (NICE 2008; SIGN 2008, C recommendation). However, the ABCD2 does not sufficiently identify the short-term risk for stroke to use alone as a risk-stratification instrument (Lo et al. [ACEP] 2016).

- The primary goal of imaging is to identify serious TIA mimics and to identify patients at high short-term risk for stroke, commonly defined as occurring within 2 or 7 days after the initial TIA event (Lo et al. [ACEP] 2016).
- Both DWI and cervical vascular imaging predict short-term risk for stroke in patients presenting with suspected TIA (Lo et al. [ACEP] 2016).
- People with crescendo TIA (two or more TIAs in a week) should be treated as being at high risk of stroke (NICE 2008; Naylor et al. [ESVS] 2018).
- Brain imaging can be helpful in the management of TIA for people being considered for carotid endarterectomy where 1) it is uncertain whether the stroke is in the anterior or posterior circulation; 2) for people with TIA where hemorrhage needs to be excluded; or 3) when alternative diagnoses are being considered (e.g., migraine, epilepsy or tumor) (NICE 2008).

Technical notes:

- Duplex ultrasound combines 2-dimensional real-time imaging with Doppler [color] flow analysis to evaluate vessels of interest and measure blood flow velocity (Brott et al. 2011).
- Carotid imaging reports should clearly state which criteria (ECST or NASCET) were used when measuring the extent of carotid stenosis (NICE 2008).
- The NASCET and ECST methods both indicate the degree of stenosis as a percentage reduction in vessel diameter. The minimum diameter of the arteries caused by stenosis (which is the maximum point of blood constriction) is compared to another diameter that represents the normal diameter of the carotid arteries when the patient is healthy. NASCET includes a measurement taken along a point of the internal carotid artery in a healthy area well beyond an area of the bulb that was caused by stenosis. The ECST formula includes the estimated normal lumen diameter at the site of the lesion, based on a visual impression of where the normal artery wall was before development of the stenosis. (NICE 2008).
- An example of a stroke-protocol for an MRI brain includes DWI, ADC, T1, T2, FLAIR, and T2 GRE or SWI sequences. This combination of sequences allows for identification of other causes for the patient's symptoms, for the detection of ischemia, and for estimation of the age of the infarct (PLE expert panel consensus statement).
- If there is concern for carotid artery dissection, axial fat-suppressed T1-weighted images through the neck should be obtained (Salmela et al. [ACR] 2016).

Evidence update (2007-present):

Redgrave et al. (2007) conducted a systematic review and meta-analysis of 19 studies on association between diffusion weighted imaging (DWI) and clinical predictors of early stroke after transient ischemic attack (TIA) in 1242 patients. Clinical risk factors were associated with positive DWI scan, symptom duration  $\geq 60$  minutes (13 studies, odds ratio [OR], 1.50; 95% CI, 1.16 to 1.96;  $P=0.004$ ), dysphasia (9 studies, OR, 2.25; 95% CI, 1.57 to 3.22;  $P<0.001$ ), dysarthria (8 studies, OR, 1.73; 95% CI, 1.11 to 2.68;  $P=0.03$ ) and motor weakness (9 studies, OR, 2.20; 95% CI, 1.56 to 3.10;  $P<0.001$ ). Atrial fibrillation (OR, 2.75; 95% CI, 1.78 to 4.25;  $P<0.001$ ) and ipsilateral  $\geq 50\%$  carotid stenosis (OR, 1.93; 95% CI, 1.34 to 2.76;  $P<0.001$ ) were associated with positive DWI. The authors conclude that presence of acute ischemic lesions on DWI correlates with several features that predict stroke risk after TIA (low level of evidence).

Ottaviani et al. (2016) conducted a prospective study on the prognostic value of ABCD2 score with or without imaging tests (urgent carotid ultrasound (CUS), unenhanced head CT (UHCT)) in 186 patients presenting with transient ischemic attack (TIA) within 24h of symptoms onset. In patients with TIA, 12 ischemic strokes (6.5%) occurred: four (7.1%) in patients with ABCD2 score less than 4 and 8 (6.2%) in

those with score  $\geq 4$ . Internal carotid stenosis of  $\geq 50\%$  was found in 15 patients (8.1%) and associated with high risk for stroke (odds ratio 4.5, 95% confidence interval 1.1–18.8). An acute ischemic lesion consistent with the neurological deficit was revealed by UHCT in 15 patients (8.1%), and associated with a trend of increasing stroke risk (odds ratio 2.5, 95% confidence interval 0.5–12.5). Patients without, with at least one, or with both positive imaging tests showed incremental stroke risk at both 7 days (2.5, 12.5, and 33%) and 30 days (5, 12.5, and 33%) ( $P < 0.05$  for both). The authors conclude that simple imaging tests showed added prognostic value to ABCD2 score in TIA patients. Urgent CUS together with UHCT should be performed in all TIA patients regardless of ABCD2 score (high level of evidence).

Tanislav et al. (2016) conducted a prospective study on characteristics associated with acute lesions in 829 young TIA patients aged 18-55 with cerebrovascular event of  $< 24$ h duration and approved MRI quality. In 121 patients (15%),  $\geq 1$  acute DWI lesion was detected. In 92 patients, DWI lesions were found in the anterior circulation, mostly located in cortical-subcortical areas ( $n = 63$ ). Factors associated with DWI lesions in multiple regression analysis were left hemispheric presenting symptoms [odds ratio (OR) 1.92, 95% CI: 1.27-2.91], dysarthria (OR 2.17, 95% CI: 1.38-3.43) and old brain infarctions on MRI (territories of the middle and posterior cerebral artery: OR 2.43, 95% CI: 1.42-4.15; OR 2.41, 95% CI: 1.02-5.69, respectively). The authors conclude that in young patients with a clinical TIA 15% demonstrated acute DWI lesions on brain MRI, with an event pattern highly suggestive of an embolic origin. Except for association with previous infarctions there was no clear clinical predictor for acute ischemic lesions, which indicates the need to obtain MRI in TIA patients (moderate level of evidence).

Amarenco et al. (2016) conducted a multicenter prospective registry on the contemporary profile, etiologic factors, and outcomes in patients (mean age 66.1) with a TIA or minor ischemic stroke within the previous 7 days who receive care in health systems that offer urgent evaluation by stroke specialists. Kaplan–Meier estimate of 1-year event rate of composite cardiovascular outcome was 6.2% (95% CI: 5.5-7.0), and estimates of stroke rate at days 2, 7, 30, 90, and 365 were 1.5%, 2.1%, 2.8%, 3.7%, and 5.1%, respectively. Multiple infarctions on brain imaging, large-artery atherosclerosis, and an ABCD score of 6 or 7 were each associated with more than a doubling of stroke risk. The authors observed a lower rate of cardiovascular events after TIA or minor stroke than that in historical cohorts. This may reflect a contemporary risk of recurrent cardiovascular events among patients with a TIA or minor stroke who are admitted to TIA clinics and who receive risk-factor control and antithrombotic treatment as recommended by current guidelines. Findings suggest that limiting urgent assessment to patients with an ABCD score of  $\geq 4$  would miss approximately 20% of those with early recurrent strokes. Multiple infarctions on neuroimaging and large-artery atherosclerotic disease were also strong independent predictors of recurrent vascular events (low level of evidence).

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## Suspected acute stroke within the treatment window for thrombolytic or endovascular therapy:

- **Green** – CT head without contrast; CT without and with contrast
- **Green** – MRI brain without contrast<sup>‡</sup>; MRI brain without and with contrast<sup>‡</sup>
- **Green** – MR cerebral perfusion
- **Green** – CT cerebral perfusion
- **Yellow** – CT head with contrast in patients with findings of intracranial hemorrhage on noncontrast CT

### Intracranial vascular imaging:

- **Yellow** – MRA head without contrast in patients who are candidates for endovascular therapy; MRA neck without contrast in patients who are candidates for endovascular therapy
- **Yellow** – MRA head with contrast in patients who are candidates for endovascular therapy; MRA neck with contrast in patients who are candidates for endovascular therapy
- **Yellow** – CTA head in patients who are candidates for endovascular therapy; CTA neck in patients who are candidates for endovascular therapy
- **Red** –CT venography, MR venography

<sup>‡</sup>MRI of the brain should include diffusion weighted imaging and gradient recalled images (GRE) or susceptibility-weighted imaging (SWI) (see technical section below).

Level of Evidence: CT head without contrast, MRI brain without contrast, CTA head without and with contrast, CTA neck with contrast, MRA neck without and with contrast MRA head without contrast, MRA neck without contrast, CT perfusion, MR perfusion: high

Notes concerning applicability and/or patient preferences: none

### Guideline and PLE expert panel consensus summary:

All patients admitted to hospital with suspected acute stroke should receive brain imaging evaluation on arrival. In most cases, noncontrast CT (NCCT) will provide the necessary information to make decisions about acute management (Powers et al. [AHA/ASA] 2018, Class I (strong) Recommendation: /Level of Evidence: B-NR).

In patients with a new focal neurologic defect, fixed or worsening, less than 6 hours, noncontrast head CT is often obtained first to assess for hemorrhage or large infarct (Salmela et al. [ACR] 2016).

Rapid neuroimaging with CT or MRI is recommended to distinguish ischemic stroke from intracerebral hemorrhage (ICH) (Hemphill et al. [AHA/ASA] 2015, Class I/Level of Evidence: A).

Either non-contrast computed tomography (CT) or magnetic resonance imaging (MRI) should be used for the definition of stroke type and treatment of stroke. MRI has a higher sensitivity than conventional CT for the documentation of infarction within the first hours of stroke onset, lesions in the posterior fossa, identification of small lesions, and documentation of vessel occlusion and brain edema (Irimia et al. 2010, Class I/Level A).

MRI with diffusion weighted and gradient echo sequences is recommended for the diagnosis of acute stroke syndromes in patients who are not severely ill, especially where neurological deficit is mild and the clinical likelihood is that the lesion is small or lies in the posterior fossa; ... (SIGN 2008, B recommendation).

In conjunction with MRI and magnetic resonance angiography (MRA), perfusion and diffusion MR are very helpful for the evaluation of patients with acute ischemic stroke (Irimia et al. 2010, Class I/Level A).

CTP may play a role to evaluate for ischemia when MRI is contraindicated or cannot be performed. Additionally, CTP has shown some promise in identifying patients who may benefit from therapy outside the accepted treatment window (Salmela et al. [ACR] 2016).

It is reasonable to use MRI systems capable of consistently generating high-quality images while avoiding low-field systems that do not yield diagnostically accurate results (Brott et al. 2011, Class IIa/Level of Evidence: C).

### **Endovascular therapy –**

Intracranial vessel occlusion must be diagnosed with non-invasive imaging whenever possible before considering treatment with mechanical thrombectomy (Wahlgren et al. [ESO] 2016; Grade A/Level 1a).

For patients who otherwise meet criteria for EVT, a noninvasive intracranial vascular study is recommended during the initial imaging evaluation of the acute stroke patient, but should not delay IV alteplase if indicated. For patients who qualify for IV alteplase according to guidelines from professional medical societies, initiating IV alteplase before noninvasive vascular imaging is recommended for patients who have not had noninvasive vascular imaging as part of their initial imaging assessment for stroke. Noninvasive intracranial vascular imaging should then be obtained as quickly as possible (Powers et al. [AHA/ASA] 2018, Class I (strong) Recommendation /Level of Evidence: A).

In patients who are potential candidates for mechanical thrombectomy, imaging of the extracranial carotid and vertebral arteries, in addition to the intracranial circulation, is reasonable to provide useful information on patient eligibility and endovascular procedural planning (Powers et al. [AHA/ASA] 2018, Class IIa (moderate) Recommendation /Level of Evidence: B-NR).

MRA or CTA may be used to define the vascular anatomy for treatment planning in the acute setting, however should not delay treatment with thrombolytic or endovascular therapy (PLE expert panel consensus opinion).

In selected patients with AIS within 6 to 24 hours of last known normal who have LVO in the anterior circulation, obtaining CTP, DW-MRI, or MRI perfusion is recommended to aid in patient selection for mechanical thrombectomy, but only when imaging and other eligibility criteria from RCTs showing benefit are being strictly applied in selecting patients for mechanical thrombectomy (Powers et al. [AHA/ASA] 2018, Class I (strong) Recommendation /Level of Evidence: A).

Duplex carotid ultrasound is not typically performed prior to thrombolytic or endovascular treatment for acute stroke. Evaluation of the extracranial carotid arteries is typically performed in the context of risk assessment and secondary prevention after treatment for the acute stroke (PLE expert panel consensus opinion; Brott et al. 2011).

[In patients treated for acute ischemic stroke with thrombectomy,] follow-up brain imaging should be performed 12-36 hours after treatment to inform therapeutic and prognostic decisions and monitor service safety and additionally whenever required by clinical circumstances (patient not clinically accessible or when therapeutic or prognostic consequences may potentially be derived for imaging findings) (Fiehler et al. 2016, quality of evidence: moderate/strength of recommendation: strong). (*This recommendation is not reflected above as follow-up imaging after treatment with thrombectomy is an in-hospital service. The recommendations in this document address primarily outpatient clinical scenarios*).

#### **Patients with intracranial hemorrhage –**

[In patients with ICH] CTA and contrast-enhanced CT may be considered to help identify patients at risk for hematoma expansion (Class IIb; Level of Evidence: B), and CTA, CT venography, contrast-enhanced CT, contrast-enhanced MRI, magnetic resonance angiography and magnetic resonance venography, and catheter angiography can be useful to evaluate for underlying structural lesions including vascular malformations and tumors when there is clinical or radiological suspicion (Hemphill et al. [AHA/ASA] 2015, Class IIa/Level of Evidence: B).

In patients with *clinically suspected parenchymal hemorrhage (hematoma), not yet confirmed* recommends CT head without IV contrast (9), MRI head without IV contrast (8), MRI head without and with IV contrast (7), and CT head without and with IV contrast (5) (Salmela et al. [ACR] 2016).

#### **ACR recommendations –**

In patients with *new focal neurologic defect, fixed or worsening, less than 6 hours, suspected stroke*, the *American College of Radiology* recommends CT head without IV contrast (9), MRI head without IV contrast (8), MRI head without and with IV contrast (8), MRA head and neck without IV contrast (8), MRA head and neck without and with IV contrast (8), CTA head and neck with IV contrast (8), CT head perfusion with IV contrast (6), MRI head perfusion with IV contrast (5), and arteriography cervicocerebral (5) (Salmela et al. [ACR] 2016).

In patients with *acute ataxia (<3 hours) as a manifestation of suspected stroke*, the *American College of Radiology* recommends MRI head without and with contrast (8), MRA head and neck without and with contrast (8), CTA head and neck with contrast (8), CT head without and with contrast (8), CT head without contrast (8), MRI head without contrast (7), CT head with contrast (7), and MRI cervical spine without and with contrast (5) (Broderick et al. [ACR] 2012).

#### Clinical notes:

- Ischemic stroke is responsible for 87% of all strokes (Salmela et al. [ACR] 2016).
- In many patients, the diagnosis of ischemic stroke can be made accurately on the basis of the clinical presentation and either a negative NCCT or one showing early ischemic changes, which can be detected in the majority of patients with careful attention (Powers et al. [AHA/ASA] 2018).
- Routine use of magnetic resonance imaging (MRI) to exclude cerebral microbleeds before administration of IV alteplase is not recommended (Powers et al. [AHA/ASA] 2018; Smith et al. [AHA/ASA] 2017). Multimodal CT and MRI, including perfusion imaging, should not delay administration of IV alteplase (Powers et al. [AHA/ASA] 2018).
- Use of imaging criteria to select ischemic stroke patients who awoke with stroke or have unclear time of symptom onset for treatment with IV alteplase is not recommended outside a clinical trial (Powers et al. [AHA /ASA] 2018, Recommendation: III-No benefit/Level B-NR Evidence).

- MRI with DWI, CT perfusion and MR perfusion imaging may be useful to evaluate patients who awoke with stroke or have unclear time of symptom onset to evaluate for treatment with thrombectomy (PLE expert panel consensus opinion).
- Imaging techniques for determining infarct and penumbra sizes can be used for patient selection and correlate with functional outcome after mechanical thrombectomy (Wahlgren et al. [ESO] 2016, Grade B, Level 1b/KSU Grade B).
- It may be reasonable to incorporate collateral flow status into clinical decision making in some candidates to determine eligibility for mechanical thrombectomy (Powers et al. [AHA/ASA] 2018, Recommendation: strong/Level A).
- Analysis of trials using advanced, multimodal pretreatment imaging (including CTP measures of penumbral imaging, diffusion-perfusion mismatch, or vessel imaging) for IV fibrinolytics has failed to demonstrate clinical efficacy in patients with various pretreatment imaging biomarkers compared with those without those markers (Powers et al. [AHA/ASA] 2018).
- For patients who otherwise meet criteria for endovascular therapy (EVT), it is reasonable to proceed with CTA if indicated in patients with suspected intracranial large vessel occlusion (LVO) before obtaining a serum creatinine concentration in patients without a history of renal impairment (Powers et al. [AHA/ASA] 2018, Recommendation: moderate/Level B-NR Evidence).
- Patients with radiological signs of large infarcts may be unsuitable for thrombectomy (Wahlgren et al. [ESO] 2016; Grade B/Level 2a).
- Rapid diagnosis and attentive management of patients with ICH is crucial, because early deterioration is common in the first few hours after ICH onset. More than 20% of patients will experience a decrease in the GCS of > 2 points between prehospital emergency medical services assessment and initial evaluation in the emergency department (Hemphill et al. [AHA/ASA] 2015).

#### Technical notes:

- The CT hyperdense MCA sign should not be used as a criterion to withhold IV alteplase from patients who otherwise qualify (Powers et al. [AHA/ASA] 2018).
- An example of a stroke-protocol MRI includes DWI, ADC, T1, T2, FLAIR, and T2 GRE or SWI sequences. This combination of sequences allows for identification of other causes for the patient's symptoms and allows the estimation of the age of the infarct (PLE expert panel consensus statement).
- If there is concern for carotid artery dissection, axial fat-suppressed T1-weighted images through the neck should be obtained (Salmela et al. [ACR] 2016).

#### Evidence update (2012-present):

Ryu et al. (2017) conducted a systematic review and meta-analysis of 13 studies regarding the utility of perfusion imaging in determining treatment eligibility in patients with acute stroke (994 treated with aid of perfusion imaging [multimodal CT scan and MRI performed as a part of stroke assessment] and 1819 treated with standard care) and in predicting clinical outcome. Of patients treated with aid of perfusion imaging, 51.1% experienced a favorable clinical outcome at 3-month follow-up compared with 45.6% of patients treated with standard care (p=0.06). Random effects modeling suggested a trend towards favoring perfusion imaging-based treatment (OR 1.29, 95% CI 0.99 to 1.69; p=0.06). Studies using multimodal therapy showed largest effect size favoring perfusion imaging (OR 1.89, 95% CI 1.44 to 2.51; p<0.01). The authors concluded that perfusion imaging may represent a complementary tool to standard radiographic assessment in enhancing patient selection for reperfusion therapy, with a subset of patients having up to 1.9 times the odds of achieving independent functional status at 3 months

(moderate level of evidence).

Vidale et al. (2017) conducted a meta-analysis of 8 studies (n = 1845) to summarize the total clinical effects of mechanical thrombectomy in patients with acute ischemic stroke due to an occlusion of arteries of proximal anterior circulation. Search criteria were represented by the use of vessel imaging to identify patients with anterior circulation ischemic stroke due to arterial occlusion. Results found that mechanical thrombectomy contributed to a significant reduction in disability rate compared to best medical treatment alone (OR: 2.09; 95% confidence interval [CI]: 1.72-2.54;  $p < .001$ ). For every 100 treated patients, 16 more participants have a good outcome as a result of mechanical treatment. The authors conclude that mechanical thrombectomy contributes to significant increases in the functional benefit of endovenous thrombolysis in patients with acute ischemic stroke caused by arterial occlusion of proximal anterior circulation, without reduction in safety (low level of evidence).

Khoury et al. (2017) conducted a randomized clinical trial comparing the therapeutic efficacy of standard care plus mechanical thrombectomy (n = 40; mean age 74) versus standard care alone (n = 37; mean age 71) in 77 patients presenting with acute ischemic stroke. All patients had suspected or proven occlusion of the M1 or M2 segments of the MCA, supraclinoid ICA, or basilar artery. Proximal occlusion was proven prior to enrollment by CT-angiography in 80% of patients of each group. The primary efficacy outcome at 3 months (mRS 0–2) was reached in 20 of 40 patients in the intervention arm (95% CI: 35%–65%) and 14 of 37 (95% CI: 24%–54%) in the standard care arm ( $P = 0.36$ ). Eleven patients in the intervention group died within 3 months compared to 9 patients in the standard care group. The authors conclude that the results support the feasibility of using care trials for patients with acute cerebrovascular disease (low level of evidence).

Wen et al. (2017) conducted a systematic review and pooled data analysis of 15 studies (total n = 487) to explore the association of baseline characteristics and outcome of patients with acute basilar artery occlusion (BAO) (confirmed by CT angiography) after stent retriever-based thrombectomy (SRT). Estimated pooled favorable outcome rate was 0.3746 (95% confidence interval [CI], 0.3165-0.4327), mortality was 0.2950 (95% CI, 0.2390-0.3510). Pooled estimates showed that successful reperfusion gained by SRT alone was 0.7317 (95% CI, 0.6532-0.8102) and final successful reperfusion rate with or without additional reperfusion procedures was 0.8834 (95% CI, 0.8279-0.9390). Seven of 15 studies excluded patients with extensive brainstem infarction using baseline brain imaging. These studies (178 patients) tended to have higher successful reperfusion rate (0.92 +/- 0.06, 0.82 +/- 0.13;  $P = 0.115$ ) and lower mortality (0.27 +/- 0.11, 0.35 +/- 0.05;  $P = 0.130$ ) than those that did not (309 patients). Favorable outcome rate was significantly higher (0.47 +/- 0.08, 0.29 +/- 0.06;  $P < 0.001$ ) in studies that reported quick brain imaging selection. The authors conclude that SRT with or without additional treatment appeared effective for the treatment of BAO (low level of evidence).

Phan et al. (2016) conducted a systematic review and meta-analysis of 17 studies (n = 491; mean age 67 years) to identify and analyze the available evidence on the safety, clinical efficacy, and complications of stent retriever thrombectomy in patients with acute basilar artery occlusions (BAOs). Three-quarters of patients were initially screened with CT and a quarter with MRI. Stent retriever thrombectomy was performed in 77% of patients, while thrombectomy with non-stent retrievers or sole use of IA thrombolytic agents was used in 21%. Weighted pooled estimates of successful recanalization (TICI 2b–3) and good outcome (modified Rankin Scale  $\leq 2$ ) were 80.0% (95% CI 70.7%-88.0%;  $I^2=80.28\%$ ;  $p<0.001$ ) and 42.8% (95% CI 34.0%-51.8%;  $I^2=61.83\%$ ;  $p=0.002$ ), respectively. It is noted that the extent of baseline ischemia is also likely to influence functional outcome. The authors conclude that mechanical thrombectomy, mainly with stent retriever, for patients with an acute symptomatic BAO can achieve

high rates of recanalization (moderate level of evidence).

Mokin et al. (2017) analyzed the accuracy of various relative cerebral blood volume (rCBV) and relative cerebral blood flow (rCBF) thresholds for predicting 27-hour infarct volume. Patients from the SWIFT PRIME study who achieved complete reperfusion based on time until the residue function reached its peak >6 s perfusion maps obtained at 27 hours were included. Final infarct volume was determined on MRI (fluid-attenuated inversion recovery images) or CT scans obtained 27 hours after symptom onset. Among the 47 subjects, the following baseline CT perfusion thresholds most accurately predicted the actual 27-hour infarct volume: rCBV=0.32, median absolute error (MAE) = 9 mL; rCBV=0.34, MAE=9 mL; rCBF=0.30, MAE=8.8 mL; rCBF=0.32, MAE=7 mL; and rCBF=0.34, MAE=7.3. The authors conclude that brain regions with rCBF 0.30-0.34 or rCBV 0.32-0.34 thresholds provided the most accurate prediction of infarct volume in patients who achieved complete reperfusion with MAEs of  $\leq 9$  (low level of evidence).

Yoo et al. (2016) examined the effect of the baseline Alberta Stroke Program Early CT Score (ASPECTS) on the safety and efficacy of intraarterial treatment in a subgroup analysis of the Multicenter Randomized Clinical Trial of Endovascular Treatment for Acute Ischemic Stroke in the Netherlands (MR CLEAN). Imaging criteria for inclusion were a CT or MRI scan ruling out hemorrhage and CT, magnetic (MR), or digital subtraction angiography showing occlusion of the intracranial internal carotid artery, middle cerebral artery (M1 or M2 segments), or anterior cerebral artery (A1 or A2 segments). A total of 496 patients, 232 (47%) in the intraarterial treatment and usual care group and 264 (53%) in the usual care alone group, were included in the subgroup analysis. The authors graded ASPECTS on baseline non-contrast CT images. The authors estimated intraarterial treatment effect for all patients in MR CLEAN who had ASPECTS graded by using multivariable ordinal logistic regression analysis to calculate the adjusted common odds ratio for a shift towards a better functional outcome according to the modified Rankin Scale (mRS) score for intraarterial treatment and usual care than for usual care alone. An interaction term was used to test for interaction with prespecified ASPECTS subgroups: 0–4 (large infarct) versus 5–7 (moderate infarct) versus 8–10 (small infarct). The authors found that, contrary to findings from previous studies suggesting that only patients with non-contrast CT ASPECTS of > 7 benefit from intraarterial treatment data from this study suggest that patients with ASPECTS 5-7 should be treated (low level of evidence).

Albers et al. (2018) conducted a multicenter randomized open-label trial on the therapeutic efficacy of endovascular therapy (thrombectomy) plus standard medical therapy (endovascular-therapy group; n = 92) compared to standard medical therapy alone (medical-therapy group; n = 90) in 182 patients with stroke onset 6 to 16 hours prior to thrombectomy. Patients had occlusion of the cervical or intracranial internal carotid artery or the proximal middle cerebral artery on CT angiography (CTA) or magnetic resonance angiography (MRA) and initial infarct volume (ischemic core) of < 70 ml, a ratio of volume of ischemic tissue to initial infarct volume of  $\geq 1.8$ , and an absolute volume of potentially reversible ischemia (penumbra) of  $\geq 15$  ml on CT or MR perfusion. Median growth volume of the infarct region between baseline and 24 hours was 23 ml in the endovascular-therapy group and 33 ml in the medical-therapy group ( $p=0.08$ ). Reperfusion > 90% of the initial perfusion lesion at 24 hours was more common in the endovascular-therapy group than medical-therapy group (79% vs. 18%,  $p<0.001$ ). The percentage of patients with complete recanalization of the primary arterial occlusive lesion at 24 hours on CTA or MRA was higher for endovascular-therapy group than medical therapy group (78% vs. 18%,  $p<0.001$ ). Mortality at 90 days was 14% in for endovascular therapy group and 26% for medical-therapy group ( $p=0.05$ ). The rate of symptomatic intracranial hemorrhage did not differ significantly between groups (7% and 4%, respectively;  $p=0.75$ ). In subgroup analysis the benefit of mechanical thrombectomy in patients with NIHSS < 10 was less certain 1.49 (0.92–2.42) although the trial was insufficiently powered

for detection. The authors conclude that among patients with acute ischemic stroke due to large-vessel occlusion who had favorable findings on perfusion imaging, endovascular therapy 6 to 16 hours after stroke onset plus standard medical therapy resulted in less disability and a higher rate of functional independence at 3 months than standard medical therapy alone (high level of evidence).

Nogueira et al. (2018) conducted a multicenter prospective randomized open-label trial on therapeutic efficacy of thrombectomy plus standard care (thrombectomy group; n = 107; mean age 69.4) compared to standard care alone (control group; n = 99; mean age 70.7) in patients with occlusion of the intracranial internal carotid artery or proximal middle cerebral artery who had last been known to be well 6 to 24 hours earlier, and who had a mismatch between the severity of clinical deficit and the infarct volume. Mismatch criteria was defined according to age with NIHSS > 10, MRS < 2. Mean score on the utility-weighted modified Rankin scale at 90 days was 5.5 in the thrombectomy group as compared with 3.4 in the control group (adjusted difference [Bayesian analysis], 2.0 points; 95% credible interval, 1.1 to 3.0; posterior probability of superiority, >0.999), and rate of functional independence at 90 days was 49% in the thrombectomy group compared to 13% in the control group (adjusted difference, 33 percentage points; 95% credible interval, 24 to 44; posterior probability of superiority, >0.999). Rate of symptomatic intracranial hemorrhage did not differ significantly between the two groups (6% in thrombectomy group and 3% in control group, P=0.50), nor did 90-day mortality (19% and 18%, respectively; P=1.00). The authors conclude that outcomes for disability were better with thrombectomy plus standard medical care than with standard medical care alone among patients with acute stroke who received treatment 6 to 24 hours after they had last been known to be well and who had a mismatch between the severity of the clinical deficit and the infarct volume, which was assessed with the use of diffusion-weighted MRI or perfusion CT and measured with the use of automated software (high level of evidence).

Guhwe et al. (2016) conducted a retrospective study on the impact of routine brain scans obtained  $\geq$  24 hours after treatment with IV-tPA in 131 clinically stable patients (mean age 66, range 28-95). A total of 62.6% of patients had CT brain scan, 12.4% had MRI brain scan, and 25% had both CT and MRI brain scans. The majority (88.9%) of MRI brain scans were completed within  $\sim$ 48 hours of admission. All patients with asymptomatic hemorrhage began antithrombotic therapy for secondary stroke prevention and pharmacological deep vein thrombosis prophylaxis between 24-48 hours of admission in accordance with AHA guideline recommendations. The authors found no utility of obtaining a routine CT or MRI brain scan 24 hours after treatment with IV-tPA to detect asymptomatic bleeding in clinically stable patients. Routine neuroimaging to evaluate for hemorrhage after IV-tPA treatment of patients with acute ischemic stroke may be able to be safely avoided in clinically stable patients, thereby eliminating unnecessary radiation exposure in those having CT brain scans (low level of evidence).

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## Stroke in patients who are not candidates for thrombolytic or endovascular therapy or patients with stroke after thrombolytic or endovascular therapy - risk stratification/secondary prevention:

- **Green** – CT head without contrast
- **Green** – MRI brain without contrast<sup>‡</sup>; MRI brain without and with contrast<sup>‡</sup>
- **Yellow** – CT head with contrast in patients with findings of intracranial hemorrhage on noncontrast CT
- **Orange** – CTA head, except if it changes patient management
- **Orange** – MRA head without contrast, except if it changes patient management
- **Orange** – MRA head with contrast, except in patients with stenting or in patients with a nondiagnostic or inconclusive MRA head without contrast if it changes patient management

### Carotid imaging:

- **Green** – MRA neck with contrast\*
- **Yellow** – MRA neck without contrast in patients unable to receive MRI contrast\*
- **Yellow** – CTA neck in a patient unable to undergo MRI\*
- **Red** – CT perfusion; MR perfusion; CT venography; MR venography; CT neck with or without contrast

<sup>‡</sup>MRI of the brain should include diffusion weighted imaging and gradient recalled imaging (GRE) or susceptibility-weighted imaging (SWI) (see technical section below).

\* Duplex carotid ultrasound is indicated for the initial evaluation of patients with suspected carotid artery stenosis.

Level of Evidence: CT head without contrast, MRI brain without contrast: moderate; CTA head without and with contrast: moderate for intracranial vascular imaging/very low for modality; CTA neck with contrast, MRA head without contrast; MRA neck without and with contrast, MRA neck without contrast: low

Notes concerning applicability and/or patient preferences: none

### Guideline and PLE expert panel consensus summary:

All patients admitted to hospital with suspected acute stroke should receive brain imaging evaluation on arrival. In most cases, noncontrast CT (NCCT) will provide the necessary information to make decisions about acute management (Powers et al. [AHA/ASA] 2018, Class I (strong) Recommendation: /Level of Evidence: B-NR).

Rapid neuroimaging with CT or MRI is recommended to distinguish ischemic stroke from intracerebral hemorrhage (ICH) (Hemphill et al. [AHA/ASA] 2015, Class I/Level of Evidence: A).

Either non-contrast computed tomography (CT) or magnetic resonance imaging (MRI) should be used for the definition of stroke type and treatment of stroke. MRI has a higher sensitivity than conventional CT for the documentation of infarction within the first hours of stroke onset, lesions in the posterior fossa, identification of small lesions, and documentation of vessel occlusion and brain edema (Irimia et al. 2010, Class I/Level A).

MRI with diffusion weighted and gradient echo sequences is recommended for the diagnosis of acute stroke syndromes in patients who are not severely ill, especially where neurological deficit is mild and the clinical likelihood is that the lesion is small or lies in the posterior fossa; or in patients who present late (after one week) (*SIGN* 2008, B recommendation).

In patients with ICH, CTA and contrast-enhanced CT may be considered to help identify patients at risk for hematoma expansion (Class IIb; Level of Evidence B), and CTA, CT venography, contrast-enhanced CT, contrast-enhanced MRI, magnetic resonance angiography and magnetic resonance venography, and catheter angiography can be useful to evaluate for underlying structural lesions including vascular malformations and tumors when there is clinical or radiological suspicion (Hemphill et al. [*AHA/ASA*] 2015, Class IIa/Level of Evidence: B).

Once the diagnosis of acute stroke has been made, the patient has been stabilized, thrombolytic and endovascular therapy has been administered if appropriate, evaluation is directed to establishing the vascular territory involved, the cause and the pathophysiology of the event. Treatment is then directed at risk stratification and secondary prevention (Brott et al. 2011; PLE expert panel consensus opinion).

#### **Carotid imaging –**

Initial carotid imaging with duplex ultrasound or alternative should be performed rapidly once a diagnosis of ischemic stroke or TIA in the carotid territory is made. Corroborative imaging (CE-MRA) is recommended to confirm and more accurately grade carotid disease if duplex carotid ultrasound is abnormal (*SIGN* 2008, C recommendation).

Duplex ultrasonography is recommended to detect carotid stenosis in patients who develop focal neurological symptoms corresponding to the territory supplied by the left or right internal carotid artery ECVD (Brott et al. 2011, Class I/Level of Evidence: C).

Duplex ultrasound (as first-line), computed tomographic angiography and/or magnetic resonance angiography are recommended for evaluating the extent and severity of extracranial carotid stenosis (Naylor et al. [*ESVS*] 2017, Class I/Level of Evidence: A).

In patients with acute, focal ischemic neurological symptoms corresponding to the territory supplied by the left or right carotid artery, magnetic resonance angiography (MRA) or computed tomography angiography (CTA) is indicated to detect carotid stenosis when sonography either cannot be obtained or yields equivocal or otherwise nondiagnostic results (Brott et al. 2011, Class I/Level of Evidence: C).

Duplex carotid ultrasonography might be considered for patients with nonspecific neurological symptoms when cerebral ischemia is a plausible cause (Brott et al. 2011, Class IIb/Level of Evidence: C).

Duplex carotid ultrasound is not typically performed prior to thrombolytic or endovascular treatment for acute stroke. Evaluation of the extracranial carotid arteries is typically performed in the context of risk assessment and secondary prevention after treatment for the acute stroke (PLE expert panel consensus opinion; Brott et al. 2011).

In patients whose symptoms suggest posterior cerebral or cerebellar ischemia, MRA or CTA is recommended rather than ultrasound imaging for evaluation of the vertebral artery (Brott et al. 2011, Class I/Level of Evidence: C).

MRA without contrast is reasonable to assess the extent of disease in patients with symptomatic carotid atherosclerosis and renal insufficiency or extensive vascular calcification (Brott et al. 2011, Class IIa/Level of Evidence: C).

CTA is reasonable for evaluation of patients with clinically suspected significant carotid atherosclerosis who are not suitable candidates for MRA (Brott et al. 2011, Class IIa/Level of Evidence: C).

It is reasonable to use MRI systems capable of consistently generating high-quality images while avoiding low-field systems that do not yield diagnostically accurate results (Brott et al. 2011, Class IIa/Level of Evidence: C).

MRA head and CTA head are not indicated in this clinical scenario unless it is used to evaluate for an underlying vascular lesion in patients with intracranial hemorrhage, or unless it changes patient management (PLE expert panel consensus opinion).

#### **ACR recommendations –**

In patients with *new focal neurologic defect, fixed or worsening, longer than 6 hours, suspected stroke*, the *American College of Radiology* recommends MRI head without IV contrast (8), MRI head without and with IV contrast (8), MRA head and neck without IV contrast (8), MRA head and neck without and with IV contrast (8), CT head without IV contrast (8), CTA head and neck with IV contrast (8), arteriography cervicocerebral (6), CT head perfusion with IV contrast (5), and MRI head perfusion with IV contrast (5) (Salmela et al. [ACR] 2016).

#### Clinical notes:

- Survivors [of stroke] face risks of recurrent stroke as high as 4% to 15% within a year after incident stroke, and 25% by 5 years (Brott et al. 2011).
- In many patients, the diagnosis of ischemic stroke can be made accurately on the basis of the clinical presentation and either a negative NCCT or one showing early ischemic changes, which can be detected in the majority of patients with careful attention (Powers et al. [AHA/ASA] 2018).
- Rapid diagnosis and attentive management of patients with ICH is crucial, because early deterioration is common in the first few hours after ICH onset. More than 20% of patients will experience a decrease in the GCS of > 2 points between prehospital emergency medical services assessment and initial evaluation in the emergency department (Hemphill et al. [AHA/ASA] 2015).

#### Technical notes:

- Carotid imaging reports should clearly state which criteria (ECST or NASCET) were used when measuring the extent of carotid stenosis (NICE 2008).
- The NASCET and ECST methods both indicate the degree of stenosis as a percentage reduction in vessel diameter. The minimum diameter of the arteries caused by stenosis (which is the maximum point of blood constriction) is compared to another diameter that represents the normal diameter of the carotid arteries when the patient is healthy. NASCET includes a measurement taken along a point of the internal carotid artery in a healthy area well beyond an area of the bulb that was caused by stenosis. The ECST formula includes the estimated normal lumen diameter at the site of the lesion, based on a visual impression of where the normal artery wall was before development of the stenosis. (NICE 2008).

- An example of a stroke-protocol MRI includes DWI, ADC, T1, T2, FLAIR, and T2 GRE or SWI sequences. This combination of sequences allows for identification of other causes for the patient's symptoms and allows the estimation of the age of the infarct (PLE expert panel consensus opinion).
- If there is concern for carotid artery dissection, axial fat-suppressed T1-weighted images through the neck should be obtained (Salmela et al. [ACR] 2016).

Evidence update (2007-present):

Liu et al. (2015) conducted an analysis of the CHANCE trial to investigate whether the efficacy and safety of clopidogrel plus aspirin vs. aspirin alone were consistent between 1,089 patients with and without intracranial arterial stenosis (ICAS). Interaction of the treatment effects of the 2 antiplatelet therapies was assessed. ICAS was identified by MRA. Patients recruited to the CHANCE trial who underwent baseline magnetic resonance examinations (3.0 or 1.5 tesla) with the following sequences were analyzed in the current subgroup analysis: T1- or T2-weighted imaging, diffusion-weighted imaging, and 3-dimensional (3D) time-of-flight magnetic resonance angiography (MRA). A total of 608 patients had ICAS; these patients had higher rates of recurrent stroke (12.5% vs. 5.4%;  $p < 0.0001$ ) at 90 days than those without. The authors conclude that higher rates of recurrent stroke were found in minor stroke or high-risk TIA patients with ICAS than those without. There was no significant difference in response to the 2 antiplatelet therapies between patients with and without ICAS (moderate level of evidence).

Kang et al. (2016) conducted a prospective study on the reliability of silent new ischemic lesions (SNIL) at 5 days (5D) or 30 days (30D) after acute ischemic stroke to predict recurrent ischemic stroke (IS) in 270 patients aged  $\geq 20$  years (mean age 62.81) with acute ischemic stroke (IS) confirmed by initial DWI performed within 24 hours of symptom onset. In patients with acute IS, 5D- and 30D-SNIL independently predicted recurrent IS (hazard ratio [95% confidence interval] 2.9 [1.3–6.4] and 9.6 [4.1–22.1], respectively). In patients with acute IS, 5D- and 30D-SNIL independently predicted composite vascular events of recurrent IS, TIA, ACS, and vascular death (HR = 2.4 [1.3–4.5] and 6.1 [3.1–12.4], respectively). The authors conclude that patients with a SNIL within the first few weeks after index stroke have increased risk of recurrent IS or vascular events (high level of evidence).

Streifler et al. (2016) evaluated the impact of prior cerebral infarction in patients previously enrolled in the Asymptomatic Carotid Surgery Trial: a large study with 10-year follow-up in which participants whose carotid stenosis had not caused symptoms for at least six months were randomly allocated to either immediate or deferred carotid endarterectomy. The first Asymptomatic Carotid Surgery Trial included 3120 patients. Of these, 2333 patients with baseline brain imaging (CT or MRI) were identified and divided into two groups irrespective of treatment assignment, 1331 with evidence of previous cerebral infarction, (history of ischemic stroke or TIA  $> 6$  months prior to randomization or radiological evidence of an asymptomatic infarct: group 1) and 1,002 with normal imaging and no prior stroke or TIA (group 2). At 10 year follow-up, stroke was more common among patients with cerebral infarction before randomization (absolute risk increase 5.8% (1.8–9.8),  $p=0.004$ ), and risk of stroke and vascular death was also higher in this group (absolute risk increase 6.9% (1.9–12.0),  $p=0.007$ ). The authors conclude that asymptomatic carotid stenosis patients with prior cerebral infarction have higher stroke risk at long-term follow-up than those without prior infarction. Evidence of prior ischemic events might help identify patients in whom carotid intervention is particularly beneficial (low level of evidence).

Andersen et al. (2016) conducted an observational cohort study on the association of silent lacunes and the risk of ischemic stroke recurrence, death, and cardiovascular events in a cohort of 786 patients (mean age 59.5 years) with incident ischemic stroke and no atrial fibrillation (AF). Number of silent

lacunes were assessed on brain MRI as none, single, or multiple. In 168 (21.5%) patients, at least one silent lacune was present, and in 87 (11.1%) patients, multiple silent lacunes were found. Patients with at least one silent lacune were older (mean age 66.1 vs. 57.7,  $p < 0.001$ ). During a median follow-up time of 2.9 years, 53 recurrent ischemic strokes, 76 deaths, and 96 cardiovascular events were observed. Incidence rates per 100 person-years of ischemic stroke recurrence were 1.6, 2.5, and 5.0 for none, single, and multiple silent lacunes, respectively. The authors conclude that an increasing number of silent lacunes was associated with increasing incidence rates of ischemic stroke recurrence. The risk of death or cardiovascular events was not significantly influenced by the presence of silent lacunes (low level of evidence).

Amarenco et al. (2016) conducted a multicenter prospective registry on the contemporary profile, etiologic factors, and outcomes in patients (mean age 66.1) with a TIA or minor ischemic stroke within the previous 7 days who receive care in health systems that offer urgent evaluation by stroke specialists. Kaplan–Meier estimate of 1-year event rate of composite cardiovascular outcome was 6.2% (95% CI: 5.5-7.0), and estimates of stroke rate at days 2, 7, 30, 90, and 365 were 1.5%, 2.1%, 2.8%, 3.7%, and 5.1%, respectively. Multiple infarctions on brain imaging, large-artery atherosclerosis, and an ABCD score of 6 or 7 were each associated with more than a doubling of stroke risk. The authors observed a lower rate of cardiovascular events after TIA or minor stroke than that in historical cohorts. This may reflect a contemporary risk of recurrent cardiovascular events among patients with a TIA or minor stroke who are admitted to TIA clinics and who receive risk-factor control and antithrombotic treatment as recommended by current guidelines. Findings suggest that limiting urgent assessment to patients with an ABCD score of  $\geq 4$  would miss approximately 20% of those with early recurrent strokes. Multiple infarctions on neuroimaging and large-artery atherosclerotic disease were also strong independent predictors of recurrent vascular events (low level of evidence).

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## Follow-up of extracranial carotid artery disease treated with carotid endarterectomy or stenting:

- **Green** – \*
- **Yellow** – MRA neck with contrast in patients for whom ultrasound is not available or for patients who have had a nondiagnostic or inconclusive ultrasound
- **Yellow** – MRA neck without contrast in patients unable to receive MR contrast and for whom ultrasound is not available, nondiagnostic or inconclusive
- **Yellow** – CTA neck in patients for whom ultrasound is not available, nondiagnostic or inconclusive
- **Red** – CT perfusion; MR perfusion; CTA head; MRA neck without and with contrast; MRA neck without contrast; CT head with contrast; CT head without and with contrast; CT neck with or without contrast; MRA head with and/or without contrast; MRI brain without and with contrast; CTA head without and with contrast; CT venography; MR venography

\*Duplex carotid ultrasound can be used to follow lesions in the extracranial carotid arteries and can be used to follow progression of disease in the contralateral artery after medical or invasive therapy.

Level of Evidence: CT head without contrast, MRI brain without contrast: moderate; CT perfusion, MR perfusion, CTA head without and with contrast, CTA neck with contrast, MRA head without contrast, MRA neck without and with contrast, MRA neck without contrast, CT head with contrast, CT head without and with contrast, MRA head with contrast, MRA head without and with contrast, CTA head without and with contrast: very low (none)

Notes concerning applicability and/or patient preferences: none

### Guideline and PLE expert panel consensus summary:

Noninvasive imaging of the extracranial carotid arteries is reasonable 1 month, 6 months, and annually after CEA or revascularization to assess patency and exclude the development of new or contralateral lesions. Once stability has been established over an extended period, surveillance at longer intervals may be appropriate. Termination of surveillance is reasonable when the patient is no longer a candidate for intervention (Brott et al. 2011, Class IIa/Level of Evidence: C).

Serial follow-up assessment most commonly involves duplex ultrasound imaging. Imaging by CTA or MRA may also be helpful for surveillance after carotid angioplasty and stenting (CAS), particularly when Doppler interrogation is difficult because of a superior anatomic location of the region of interest (Brott et al. 2011).

Serial non-invasive imaging of the extracranial vertebral arteries may be considered in patients who have undergone open or endovascular interventions (Naylor et al. [ESVS] 2018, Class IIb/Level of Evidence: C).

Clinical/Technical notes: none

### Evidence update (no date limit):

There was no new low, moderate or high quality evidence which significantly affect the evidence and

recommendations included in the guidelines cited above.

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## Suspected cerebral venous thrombosis (CVT):

- **Green** – MRI brain without and with contrast; MR venography without and with contrast; MR venography with contrast
- **Yellow** – MRI brain without contrast in patients unable to receive MR contrast; MR venography without contrast (TOF venography) in patients unable to receive MR contrast
- **Yellow** – CT head with and/or without contrast; CT venography\*
- **Red** – CTA head or neck; MRA head or neck without and/or with contrast; CT perfusion; MR perfusion; CT neck with or without contrast;

\*CT utilizes ionizing radiation and iodinated contrast, however is often more available in the acute or urgent setting.

Level of Evidence: CT head, MRI brain without contrast, CTA head without and with contrast, MRA head without and with contrast: low

Notes concerning applicability and/or patient preferences: none

### Guideline and PLE expert panel consensus summary:

Although a plain CT or MRI is useful in the initial evaluation of patients with suspected cerebral venous thrombosis (CVT), a negative plain CT or MRI does not rule out CVT. A venographic study (either CTV or MRV) should be performed in suspected CVT if the plain CT or MRI is negative or to define the extent of CVT if the plain CT or MRI suggests CVT (Saposnik et al. [AHA/ASA] 2011, Class I/Level of Evidence: C).

An MRV or CTV should be performed if hemorrhage location, relative edema volume, or abnormal signal in the cerebral sinuses on routine neuroimaging suggests cerebral vein thrombosis (Hemphill et al. [AHA/ASA] 2015).

MRI with [MRV] is recommended for the diagnosis and follow-up of cerebral venous thrombosis (Class II, Level B). Alternatively, CT venography is accurate and can be used for the same purpose (Irimia et al. 2010, Class III/Level C).

In patients with previous CVT who present with recurrent symptoms suggestive of CVT, repeat CTV or MRV is recommended (Saposnik et al. [AHA/ASA] 2011, Class I/Level of Evidence: C).

An early follow-up CTV or MRV is recommended in CVT patients with persistent or evolving symptoms despite medical treatment or with symptoms suggestive of propagation of thrombus (Saposnik et al. [AHA/ASA] 2011, Class I/Level of Evidence: C).

A follow-up CTV or MRV at 3 to 6 months after diagnosis is reasonable to assess for recanalization of the occluded cortical vein/sinuses in stable patients (Saposnik et al. [AHA/ASA] 2011, Class IIa/Level of Evidence: C).

Intra-arterial four-vessel angiography has long been the gold standard for establishing the diagnosis of CVST but today magnetic resonance imaging (MRI) and magnetic resonance [venography (MRV)] are regarded the best tools both for the diagnosis and follow-up of CVST. Cranial computed tomography

(CCT) alone is not sufficient but diagnosis can be established in combination with CT angiography although the use of iodinated contrast fluid and ionizing radiation remains a disadvantage which makes it inappropriate for follow-up examinations (Einhaupl et al. [EFNS] 2010).

In patients with *suspected dural venous sinus thrombosis*, the *American College of Radiology* recommends MR venography head without and with IV contrast (9), MR venography head without IV contrast (8), CT venography head with IV contrast (8), MR venography head and neck without and with IV contrast (8), CT head without and with IV contrast (7), CT head without IV contrast (7), MRI head without and with IV contrast (7), MRI head without IV contrast (7), CT venography head and neck with IV contrast (7), CT head with IV contrast (6), MR venography head and neck without IV contrast (6), and catheter venography cervicocerebral (5) (Salmela et al. [ACR] 2016).

#### Clinical notes:

- CVT is an uncommon cause for stroke, affecting 0.5%-2% of stroke patients (Salmela et al. [ACR] 2016; Saposnik et al. [AHA/ASA] 2011).
- Patients can present with headaches, seizures, or decreased level of consciousness (Saposnik et al. [AHA/ASA] 2011).
- In patients with headache associated with atypical features, imaging of the cerebral venous system is reasonable to exclude CVT (Class IIa/Level of Evidence C). For patients with isolated headache, the proper strategy for identification of CVT is much less clear (Saposnik et al. [AHA/ASA] 2011). The vast majority of patients with isolated headache will not have CVT (PLE expert panel consensus opinion; Saposnik et al. [AHA/ASA] 2011).
- Factors that may suggest the diagnosis [of CVT] and thus prompt imaging evaluation, include a new atypical headache; headache that progresses steadily over days to weeks despite conservative treatment; and thunderclap headache (Saposnik et al. [AHA/ASA] 2011).
- Predisposing conditions for CVT and principles in favor of a cause-and-effect relationship include prothrombotic conditions, pregnancy, puerperium, oral contraceptives, parameningeal infections, or cancer (Saposnik et al. [AHA/ASA] 2011).
- In patients with lobar ICH of otherwise unclear origin or with cerebral infarction that crosses typical arterial boundaries, imaging of the cerebral venous system should be performed (Saposnik et al. [AHA/ASA], Class I/Level of Evidence).
- In patients with the clinical features of idiopathic intracranial hypertension, imaging of the cerebral venous system is recommended to exclude CVT (Saposnik et al. [AHA/ASA], Class I/Level of Evidence C).
- In patients with a history of CVT who complain of new, persisting, or severe headache, evaluation for CVT recurrence and intracranial hypertension should be considered (Saposnik et al. [AHA/ASA] 2011, Class I/Level of Evidence C).
- Catheter cerebral angiography can be useful in patients with inconclusive CTV or MRV in whom a clinical suspicion for CVT remains high (Saposnik et al. [AHA/ASA] 2011, Class IIa/Level of Evidence C).

#### Technical notes:

- Direct signs [of CVT] on unenhanced CT are the cord sign, corresponding to thrombosed cortical veins, and the dense triangle sign, corresponding to a thrombus in the superior sagittal sinus, and, on enhanced CT of the sagittal sinus, the delta sign (Irimia et al. 2010, Saposnik et al. [AHA/ASA] 2011).

- Indirect signs such as local hypodensities caused by edema or infarction, hyperdensities secondary to hemorrhagic infarction, or brain swelling and small ventricles suggest the diagnosis of CVT (Irimia et al. 2010).
- Contrast-enhanced CT may show enhancement of the dural lining of the sinus with a filling defect in the vein or sinus (Saposnik et al. [AHA/ASA] 2011).
- Gradient echo T2 susceptibility-weighted images combined with magnetic resonance can be useful to improve the accuracy of CVT diagnosis (Saposnik et al. [AHA/ASA] 2011, Class IIa/Level of Evidence B).
- If there is suspicion for CVT after the initial NCCT is performed in the acute setting, CTV can be quickly performed while the patient is still on the CT scan table. In a less acute setting or an acute setting where MRI is readily available without contraindications, contrast-enhanced brain MRI and MRV are often performed for optimal evaluation (Salmela et al. [ACR] 2016).

Evidence update (2010-present):

Alons et al. (2015) conducted a meta-analysis of 8 studies on the diagnostic accuracy and diagnostic yield of the D-dimer test in 636 patients with isolated headache and suspected CVT. A total of 45 (7.5%) CVT patients had a negative D-dimer. Sensitivity of D-dimer for diagnosing CVT was 97.8 % (95 % CI: 88.2–99.6 %), specificity was 84.9 % (95 % CI: 81.8–87.7 %), PPV was 33.1 % (95 % CI: 25.2–41.7 %), and NPV was 99.8 % (95 % CI: 98.9–100 %). The authors conclude that D-dimers have a high negative predictive value in patients with isolated headache for excluding CVT (moderate level of evidence).

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## Suspected central nervous system (CNS) vasculitis presenting with stroke:

- **Green** – CT head without contrast
- **Green** – MRI brain without contrast<sup>‡</sup>; MRI brain without and with contrast<sup>‡</sup>
- **Green** – MRA head with and without IV contrast; MRA head with IV contrast; MRA head without IV contrast
- **Green** – CTA head
- **Yellow** – CT head with contrast in patients who are unable to undergo MRI

### Neck imaging:

- **Yellow** – MRA neck with contrast if systemic large vessel vasculitis is suspected
- **Yellow** – CTA neck if systemic large vessel vasculitis is suspected
- **Yellow** – MRA neck without contrast if systemic large vessel vasculitis is suspected and the patient has a contraindication to contrast
  
- **Red** – CT neck with or without contrast; CT perfusion; MR perfusion; CT venography; MR venography

<sup>‡</sup> MRI of the brain should include diffusion-weighted imaging and gradient recalled imaging or susceptibility-weighted imaging (see recommendations in the technical notes).

Level of Evidence: CT head, MRI brain without contrast, CTA head without and with contrast, CTA neck with contrast, MRA head without and with contrast: low

Notes concerning applicability and/or patient preferences: none

### Guideline and PLE expert panel consensus summary:

In the evaluation of CNS vasculitis, CE-MRI and MRA of the head and neck are the initial imaging studies of choice to evaluate for vessel narrowing/dilation/occlusion of large- and medium-vessels, scattered white matter T2 hyperintensities, and scattered infarcts in different vascular territories (Salmela et al. [ACR] 2016).

In patients with *central nervous system vasculitis*, the *American College of Radiology* (Salmela et al. [ACR] 2016) recommends MRI head without and with IV contrast (8), MRA head without and with IV contrast (8), MRA head without IV contrast (8), arteriography cervicocerebral (8), CTA head with IV contrast (8), MRA head and neck without and with IV contrast (7), MRA head and neck without IV contrast (7), CTA head and neck with IV contrast (7), MRI head without IV contrast (7), and CT head without IV contrast (5).

### Clinical notes:

- The clinical presentation [of CNS vasculitis] is highly variable and includes ischemic stroke, hemorrhagic stroke, seizure, migraine, psychiatric disease, and cognitive decline (Salmela et al. [ACR] 2016).
- US can be used in the evaluation for extracranial vasculitis, including fibromuscular dysplasia and giant cell arteritis decline (Salmela et al. [ACR] 2016).
- Conventional angiography remains the gold standard imaging study for evaluation of large- and medium-vessel narrowing, dilation, or occlusion in CNS vasculitis (Salmela et al. [ACR] 2016).

- If MRA is negative and vasculitis is still suspected, conventional angiography should then be performed (Salmela et al. [ACR] 2016).

Technical notes:

- Direct imaging findings of CNS vasculitis include vessel wall enhancement and thickening, and indirect imaging findings include vessel narrowing, dilation, occlusion, and a beaded appearance as well as scattered nonspecific white-matter T2 hyperintensities on MRI, scattered infarcts in different vascular territories, perfusion defects, and hemorrhage (Salmela et al. [ACR] 2016).
- High-resolution contrast-enhanced MRI at 3T can be used to evaluate for direct signs of vasculitis, including wall thickening and enhancement in large- and medium-sized vessels (Salmela et al. [ACR] 2016).
- An example of a stroke-protocol for an MRI brain includes DWI, ADC, T1, T2, FLAIR, and T2 GRE or SWI sequences. This combination of sequences allows for identification of other causes for the patient's symptoms, for the detection of ischemia, and for estimation of the age of the infarct (PLE expert panel consensus statement).

Evidence update (no date limit):

Boulouis et al. (2017) conducted a case series of 60 patients (mean age 45) with primary angiitis of the central nervous system (PACNS). Acute ischemic lesions were observed in 75% of patients at time of diagnosis. The most common MRI finding observed in 42% of patients was multiterritorial, bilateral, distal acute stroke lesions after small to medium artery distribution, with a predominant carotid circulation distribution. Seventy-seven percent of magnetic resonance angiographic studies were abnormal, revealing proximal/distal stenoses in 57% and 61% of patients, respectively. The authors conclude that PACNS diagnosis with neuroimaging remains difficult given the wide variety of imaging characteristics and the poor specificity of each finding taken separately (low level of evidence).

**Guideline exclusions:**

- Blunt or penetrating trauma
- Detection or follow-up of isolated intracranial aneurysm
- Detection or follow-up of cerebrovascular malformation(s)
- Suspected or known subarachnoid hemorrhage (thunderclap headache)
- MR arterial spin labelling
- Transcranial Doppler (TCD) ultrasonography
- Pediatric patients and
- Pregnant patients.