

6.01.49	Computed Tomography Perfusion Imaging of the Brain		
Original Policy Date:	June 28, 2007	Effective Date:	November 1, 2020
Section:	6.0 Radiology	Page:	Page 1 of 20

Policy Statement

Computed tomography perfusion (CTP) imaging may be considered **medically necessary** to select patients with anterior large-vessel stroke for mechanical embolectomy.

Computed tomography perfusion (CTP) imaging of the brain is considered **investigational** for all other indications.

Policy Guidelines

Selection criteria for the EXTEND-IA trial included patients with an anterior large-vessel stroke who: were receiving a tissue plasminogen activator; were able to receive endovascular therapy within 6 hours of stroke onset; were functionally independent prior to the stroke; and had evidence of salvageable brain tissue and an ischemic core with a volume of less than 70 mL on computed tomography perfusion imaging.

Coding

There is a CPT category III code specific to this test:

- **0042T**: Cerebral perfusion analysis using computed tomography with contrast administration, including post-processing of parametric maps with determination of cerebral blood flow, cerebral blood volume, and mean transit time

Description

Computed tomography perfusion (CTP) imaging provides an assessment of cerebral blood flow that may help identify ischemic regions of the brain. This technology is proposed to aid treatment decisions in patients being evaluated for acute ischemic stroke, subarachnoid hemorrhage, cerebral vasospasm, brain tumors, and head trauma.

Related Policies

- Endovascular Procedures for Intracranial Arterial Disease (Atherosclerosis and Aneurysms)

Benefit Application

Benefit determinations should be based in all cases on the applicable contract language. To the extent there are any conflicts between these guidelines and the contract language, the contract language will control. Please refer to the member's contract benefits in effect at the time of service to determine coverage or non-coverage of these services as it applies to an individual member.

Some state or federal mandates (e.g., Federal Employee Program [FEP]) prohibits plans from denying Food and Drug Administration (FDA)-approved technologies as investigational. In these instances, plans may have to consider the coverage eligibility of FDA-approved technologies on the basis of medical necessity alone.

Regulatory Status

Several postprocessing software packages (e.g., Siemens' syngo® Perfusion-CT, GE Healthcare's CT Perfusion 4, Philips Medical System's Brain Perfusion Option) have been cleared for marketing by the U.S. Food and Drug Administration (FDA) for use with a CT system to perform perfusion imaging. The software is being distributed with new CT scanners. FDA product code: JAK.

Rationale

Background

Acute Stroke

The goal of acute stroke thrombolytic treatment is to rescue the ischemic penumbra, an area of the brain that surrounds the infarct core and is hypoperfused but does not die quickly. Multi-modal computed tomography (CT) and magnetic resonance imaging (MRI) can be used to assess the cerebral parenchyma, vasculature, and tissue viability in the acute ischemic stroke setting and are used to detect ischemic tissue and exclude hemorrhage and other conditions that mimic acute cerebral ischemia.

Non-contrast CT is used to rule out intracranial hemorrhage, tumor, or infection. Diffusion-weighted MRI is used to identify acute infarction, and a gradient-recalled echo sequence is used to exclude intracerebral hemorrhage.

CT angiography and magnetic resonance angiography are used to evaluate intra- and extracranial vasculature to detect the vascular occlusion and potentially guide therapy (e.g., intravenous thrombolysis or mechanical thrombectomy).

The approved thrombolytic therapy, an intravenous tissue plasminogen activator, requires only a non-contrast CT scan to exclude the presence of hemorrhage (a contraindication to use of the drug). Current guidelines are to administer tissue plasminogen activator within the first 3 hours after an ischemic event, preceded by a CT scan. Many patients, however, do not present to the emergency department within the 3 hour window, and thrombolysis carries a risk of intracranial hemorrhage. Thus, more sophisticated imaging may be needed to inform the proper use of intra-arterial thrombolysis or mechanical thrombectomy in patients who present more than 3 hours after an ischemic stroke. Perfusion imaging is also being evaluated in the management of other neurologic conditions, such as subarachnoid hemorrhage and head trauma.

The potential utility of perfusion imaging for acute stroke is as follows:

- identification of brain regions with extremely low cerebral blood flow, which represent the core
- identification of patients with at-risk brain regions (acutely ischemic but viable penumbra) that may be salvageable with successful intra-arterial thrombolysis beyond the standard 3 hour window
- triage of patients with at-risk brain regions to other available therapies, such as induced hypertension or mechanical clot retrieval
- decisions regarding intensive monitoring of patients with large, abnormally perfused brain regions
- biologically based management of patients who awaken with a stroke for which the precise time of onset is unknown.

Additional potential uses of CT perfusion (CTP) in acute stroke may include the following:

- detection and differential diagnosis (e.g., excluding stroke mimics such as a transient ischemic attack, complex migraine, seizure, conversion disorders, hypoglycemia, brain tumors)
- determination of stroke subtype
- determination of stroke extent, including additional vascular territories at risk

- identification of patients at high early risk of stroke following a transient ischemic attack
- determining the need for blood pressure management
- establishing prognosis.

Similar information can be provided by CT and MRI regarding infarct core and penumbra. However, multimodal CT has a short protocol time (5-6 minutes) and, because it can be performed with any modern CT equipment, is more widely available in the emergency department setting. CTP is performed by capturing images as an iodinated contrast agent bolus passes through the cerebral circulation and accumulates in the cerebral tissues. (Older perfusion methodologies such as single-photon emission CT and xenon-enhanced CT scanning use a diffusible tracer.) The quantitative perfusion parameters are calculated from density changes for each pixel over time with the commercially available deconvolution-based software, in which cerebral blood flow is equal to regional cerebral blood volume divided by mean transit time. CT angiography and CTP imaging require ionizing radiation and iodinated contrast. It is estimated that typical CTP imaging deposits a slightly greater radiation dose than a routine unenhanced head CT (≈ 3.3 mSv).

Subarachnoid Hemorrhage and Cerebral Vasospasm

Cerebral vasospasm is a major cause of morbidity and mortality following aneurysmal SAH in patients who survive the initial hemorrhage and can be seen in about two-thirds of patients with aneurysmal SAH. The typical onset of cerebral vasospasm occurs 3 to 5 days after hemorrhage, with maximal narrowing on digital subtraction angiography at 5 to 14 days. Currently, the diagnosis of vasospasm and the management decisions rely on clinical examination, transcranial Doppler sonography, and digital subtraction angiography. Although symptomatic vasospasm affects 20% to 30% of patients with aneurysmal SAH, not all patients with angiographic vasospasm manifest clinical symptoms, and the symptoms can be nonspecific. Also, patients do not always have both clinical and imaging findings of vasospasm. Due to these limitations, more accurate and reliable methods to detect cerebral vasospasm are being investigated.

Brain Tumors

The current standard for tumor grading is a histopathologic assessment of tissue. Limitations of histologic assessment include sampling error due to regional heterogeneity and interobserver variation. These limitations can result in inaccurate classification and grading of gliomas. Because malignant brain tumors are characterized by neovascularity and increased angiogenic activity, perfusion imaging has been proposed as a method to assess tumor grade and prognosis. Also, perfusion imaging can be repeated and may help to assess the evolution of tumors and the treatment response. Traditionally, perfusion imaging of brain tumors has been performed with MRI, which can estimate tumor blood volume, blood flow, and permeability. More recently, CTP imaging has been investigated for glioma grading. Potential advantages, compared with magnetic resonance perfusion, include the wider availability, faster scanning times, and lower cost. CTP imaging may also be used to distinguish recurrent tumor from radiation necrosis.

Literature Review

Evidence reviews assess whether a medical test is clinically useful. A useful test provides information to make a clinical management decision that improves the net health outcome. That is, the balance of benefits and harms is better when the test is used to manage the condition than when another test or no test is used to manage the condition.

The first step in assessing a medical test is to formulate the clinical context and purpose of the test. The test must be technically reliable, clinically valid, and clinically useful for that purpose. Evidence reviews assess the evidence on whether a test is clinically valid and clinically useful. Technical reliability is outside the scope of these reviews, and credible information on technical reliability is available from other sources.

Acute Stroke**Clinical Context and Test Purpose**

The purpose of computed tomography perfusion (CTP) imaging in patients with acute stroke is to guide treatment decisions.

The question addressed in this evidence review is: Does the use of CTP improve the net health outcome of patients with acute stroke?

The following PICO was used to select literature to inform this review.

Patients

The relevant population of interest is patients with acute stroke who are being evaluated for thrombolysis or mechanical embolectomy, and patients with acute stroke who are being evaluated for prognosis.

Interventions

The interventions of interest are CTP imaging as an add-on to non-contrast computed tomography (NCCT) and computed tomography angiography (CTA).

Comparators

The following practice is currently being used to make decisions about managing acute stroke: standard stroke management without CTP (e.g., NCCT, CTA).

Outcomes

The outcomes of interest are function measured with the National Institutes of Health Stroke Scale (NIHSS) or modified Rankin Scale (mRS) scores at least 90 days following thrombolysis or mechanical embolectomy.

Technically Reliable

Assessment of technical reliability focuses on specific tests and operators and requires a review of unpublished and often proprietary information. Review of specific tests, operators, and unpublished data are outside the scope of this evidence review and alternative sources exist. This evidence review focuses on the clinical validity and clinical utility.

Clinically Valid

A test must detect the presence or absence of a condition, the risk of developing a condition in the future, or treatment response (beneficial or adverse).

Evaluation for Thrombolysis

No head-to-head randomized controlled trials (RCTs) were identified that directly compared CTP imaging-guided thrombolytic therapy vs thrombolytic therapy guided by another imaging modality. The best available evidence assessing that comparison comes from a study by Bivard et al (2015) that compared the qualitative analysis of CTP imaging (n=366) to historical controls (n=396) selected for tissue plasminogen activator (tPA) based on clinical and NCCT information. ¹ Patients selected for tPA based on qualitative analysis of CTP imaging had higher odds of an excellent outcome (mRS score, 0-1; odds ratio [OR], 1.59; p=0.009) and lower mortality (OR, 0.56; p=0.021) than historical controls. In addition, of patients treated with tPA, those who had a target mismatch by CTP imaging had significantly better outcomes than patients treated with tPA who did not (OR, 13.8 for 3-month mRS score, ≤ 2). However, 83 (31%) of 269 untreated patients had target mismatch, and 56 (15%) of 366 treated patients had a large ischemic core. This observational study suggested that CTP imaging might identify those patients with acute stroke who are likely and unlikely to respond to thrombolysis. However, questions remain about whether CTP imaging is sufficiently reliable to select stroke patients for treatment.^{2,3}

Additionally, Burton et al (2015) performed a meta-analysis of 13 small but generally good-quality studies (including 3 RCTs and 6 prospective cohort studies) that used CTP imaging and

provided intravenous thrombolytic treatment (Tables 1 and 2).⁴ The objectives of the studies included comparisons of thrombolytic agents and predictions of clinical outcomes. Relatively few patients received tPA based on CTP imaging results. However, the authors reported rates of 90-day mortality, mRS scores ≤ 2 and in-hospital symptomatic intracranial hemorrhage (Table 2) that they indicated “are comparable with those in studies that used other image modalities.” Nonetheless, to more definitively determine the clinical utility of CTP imaging, RCTs are still needed that directly compare thrombolytic therapy guided by CTP imaging versus other imaging modalities.

Table 1. Thrombolysis SR & M-A Characteristics

Study	Dates	Trials	Participants ¹	N (Range)	Design	Duration
Burton 2015	Search dates: 1946-2012; Publication dates:	13	Patients with acute ischemic stroke who underwent perfusion CT neuroimaging for thrombolytic therapy selection	557 (2 to 140)	RCTs (3), prospective cohorts (7), retrospective cohorts (3)	In hospital to 90 days

CT: computed tomography; M-A: meta-analysis; RCT: randomized controlled trial; SR: systematic review.

Table 2. Results from Burton 2015 Systematic Review (all patients selected for thrombolysis using CTP)

Study		90-day mortality	mRS score ≤ 2 at 90 days	In-Hospital SICH
All patients	Total N	118	100	171
	Pooled effect (95% CI)	10.0% (5.4% to 15.9%)	59.4% (38.2% to 78.9%)	3.6% (1.4% to 6.8%)
	I^2	0	73.1	0
Treated ≤ 3 hrs	Total N	95	47	94
	Pooled effect (95% CI)	12.5% (6.7% to 19.7%)	42.5 (16.6% to 70.9%)	3.3% (0.7% to 7.7%)
	I^2	0	N/A	0
Treated > 3 hrs	Total N	23	53	77
	Pooled effect (95% CI)	2.9% (0% to 12.7%)	69.9% (0% to 83.5%)	3.9% (0.8% to 9.2%)

CI: confidence interval; CT: computed tomography; mRS: modified Rankin Scale; NA: not available; SICH: symptomatic intracranial hemorrhage.

Another area of research is whether CTP imaging can help select ischemic stroke patients for thrombolysis after the standard 4.5-hour time window. In the newly published international EXTEND RCT (Extending the Time for Thrombolysis in Emergency Neurological Deficits),⁵ when automated CT or magnetic resonance imaging (MRI) perfusion imaging was used in all patients (median NIHSS score range, 10 to 12) to detect hypoperfused but salvageable regions of the brain, more patients randomized to receive intravenous alteplase up to 9 hours after stroke onset ($n=113$) had no or minor neurological deficits than those who received placebo ($n=112$) (35.4% vs 29.4%; adjusted rate ratio 1.44, 95% CI, 1.01 to 2.06). However, symptomatic intracerebral hemorrhage occurred in a nonsignificantly greater number of patients in the alteplase group (6.2% vs 0.9%; adjusted rate ratio 7.22, 95% CI, 0.97 to 53.5). Although EXTEND provides information about the clinical utility of perfusion imaging *in general* to guide thrombolysis beyond 4.5 hours, strong conclusions cannot be drawn about CTP specifically. This is because patients in the EXTEND RCT received perfusion imaging by either CT or MRI and no information was provided about what proportion received CT, nor were the results stratified by perfusion imaging type. However, a previous systematic review⁴ and 2 previous prospective cohort studies^{6,7} consistently found that use of CTP imaging to select patients for thrombolysis after 3 hours or 4.5 hours post-acute stroke led to generally favorable outcomes compared to using CTP imaging to select patients for treatment within 3 hours⁴ and compared to using NCCT to select patients for treatment within 3 hours⁷ or 4.5 hours.⁶ In the prospective cohort study by Garcia-

Bemejo et al (2012) that compared outcomes between 172 patients treated within 4.5 hours based on NCCT criteria and 43 patients treated after 4.5 hours based on CTP mismatch criteria, there were similar rates of symptomatic intracranial hemorrhagic (2.9% in the <4.5-hour group vs 2.3% in the >4.5-hour group) and good long-term outcome (64.5% vs 60.5%, respectively) in both groups. Similarly, a prospective cohort study by Medina-Rodriguez et al (2020) compared 53 patients receiving CTP with 657 control patients receiving standard of care to guide selection of thrombolysis within 4.5 hours of stroke onset.⁸ The authors found no significant differences between groups at 90 days in symptomatic intracranial hemorrhage (3.8% vs 3.8%; $p = 1.0$) and $mRS < 2$ (72.0% vs 60.4%; $p = 0.107$). These findings support further study in a randomized trial.

Subsection Summary: Evaluation for Thrombolysis

Evidence from nonrandomized comparative studies with either concurrent or historical controls has suggested that outcomes after thrombolysis are better in patients who have target mismatch on perfusion imaging than in patients without target mismatch. Evidence from an RCT (EXTEND) and nonrandomized comparative studies also provides general support of the clinical rationale of selecting patients for thrombolysis based on perfusion imaging (MRI or CTP) after a 3- or 4.5-hour time window. The EXTEND RCT had the potential to establish a general clinical rationale of using CTP imaging to select patients for thrombolysis. However, the net health benefit is not clear because the magnitude of improvement on the primary outcome of mRS of 0 or 1 at 90 days was modest and inconsistent between adjusted and unadjusted analyses, there was no significant difference on the secondary outcome of functional improvement, and there was a large increased risk of symptomatic intracranial hemorrhage. Also, the EXTEND RCT had important methodological and relevance limitations, including (1) baseline imbalance in age and NIHSS; (2) indirect intervention – CT or MRI with no stratification; and (3) not an optimal comparator. Therefore, further RCTs are still needed to provide greater certainty whether a strategy employing CTP imaging leads to improved health outcomes compared with traditional treatment strategies for acute stroke.

Evaluation for Mechanical Embolectomy

Randomized Controlled Trials

The clinical utility of CTP imaging-based patient selection for thrombectomy has not yet been proven in an RCT in which inclusion of patients was not based on perfusion imaging findings. Numerous RCTs have shown that in patients with ischemic stroke with a proximal cerebral artery or internal carotid artery occlusion that were selected based on having a region of salvageable tissue on CTP imaging, thrombectomy within 6 hours,⁹ at 6 to 16 hours¹⁰ and at 6 to 24 hours¹¹ results in better outcomes than standard medical therapy alone. Also, it should be noted that other comparable trials of mechanical embolectomy from the same period (e.g., Randomized Assessment of Rapid Endovascular Treatment of Ischemic Stroke, Multicenter Randomized Clinical Trial of Endovascular Treatment for Acute Ischemic Stroke in The Netherlands [MR CLEAN], Solitaire with the Intention for Thrombectomy as Primary Endovascular Treatment for Acute Ischemic Stroke) also used time from stroke onset, multiphase CTA, or Alberta Stroke Program Early CT Score to select patients for treatment.^{12,13,14} Overall, these trials found a significant benefit of mechanical embolectomy with stent retrievers, and generally support a clinical rationale for CTP imaging-based patient selection. (See Blue Shield of California Medical Policy: Endovascular Procedures for Intracranial Arterial Disease [Atherosclerosis and Aneurysms], which addresses endovascular procedures for intracranial arterial disease, for discussion of these trials.) However, such studies do not allow any conclusions on whether CTP imaging can reliably differentiate between those who will and will not benefit from thrombectomy.

One of the most recent RCTs that used CTP imaging-based patient selection for thrombectomy was DEFUSE 3 (Endovascular Therapy Following Imaging Evaluation for Ischemic Stroke) by Albers et al (2018), which compared endovascular therapy plus medical therapy ($n=92$) with medical therapy alone ($n=90$).¹⁰ DEFUSE 3 enrolled patients with proximal middle-cerebral-artery or internal-carotid-artery occlusion based on whether their initial infarct volume was ≤ 70 mL, their ratio of volume of ischemic tissue to initial infarct volume was ≥ 1.8 , and their absolute volume of potentially reversible ischemia was ≥ 15 mL. Infarct and ischemia parameters were calculated

using automated image processing software (RAPID) following selective application of either CTP (73%) or MRI diffusion and perfusion scans (27%). Enrollment was planned for up to 476 patients over 4 years but it was stopped early for efficacy after enrolling 182 patients. DEFUSE 3 was designed to evaluate the effectiveness of endovascular treatment initiated later than the recommended 6 hours after patients were last seen well (6-16 hours) and had the primary outcome of the ordinal score on the mRS at 90 days. Patients were 51% female, had a median age of 70 years, and a median NIHSS score of 16.

Compared to medical therapy alone in DEFUSE 3, thrombectomy improved the 90-day mRS (median scores, 3 vs 4; OR, 2.77; 95% CI, 1.63 to 4.70) and rate of 90-day functional independence (45% vs 17%; OR, 2.67, 95% CI, 1.60 to 4.48). Additionally, there were no differences in 90-day death (14% vs 26%; OR, 0.55; 95% CI, 0.30 to 1.02) or symptomatic intracranial hemorrhage (7% vs 4%; OR 1.47, 95% CI, 0.40 to 6.55).¹⁰ Furthermore, in a sensitivity analysis based on imaging modality (CT vs MRI), there was no interaction by modality type in the effects of thrombectomy on 90-day functional independence. However, small sample size, selection bias (CT and MRI selectively used) and potential for residual confounding (no multivariable regression) are major limitations of the subanalysis.

Consistent with DEFUSE 3,¹⁰ the DAWN RCT (DWI or CTP Assessment with Clinical Mismatch in the Triage of Wake-Up and Late Presenting Strokes Undergoing Neurointervention with Trevo)¹¹ and the EXTEND-IA (Extending the Time for Thrombolysis in Emergency Neurological Deficits)⁹ provide evidence that CTP imaging may be useful in identifying people who may benefit from thrombectomy at within 6 hours⁹ and 6 to 24 hours after stroke.¹¹ However, because neither DAWN nor EXTEND-IA involves a comparison of patients who were selected for thrombectomy using other non-CTP imaging approaches or who were not selected for thrombectomy, these RCTs also do not provide definitive evidence of the clinical utility of CTP imaging.

Also, findings from 2 previous nonrandomized studies ^{15,16} have raised questions about whether CTP imaging can reliably differentiate between those who will and will not benefit from thrombectomy. First, a subanalysis of data from the MR CLEAN trial by Borst et al (2015) suggests that CTP imaging cannot reliably identify patients who would not benefit from mechanical embolectomy.¹⁵ In this trial, inclusion was not limited to CTP imaging, so CTP was permitted if it were standard procedure at an institution. Of 500 patients in MR CLEAN, 333 (67%) underwent CTP imaging. Of 175 (52.6%) patients with adequate images, 102 fulfilled the CTP mismatch criteria. The primary outcome, mRS score at 90 days, was assessed for patients with and without CTP mismatch. There was no significant interaction for mismatch and treatment (mechanical embolectomy or usual care) for the mRS score at 90 days, suggesting that CTP imaging cannot reliably identify patients who would not benefit from mechanical embolectomy. In both treatment groups, there was a shift toward better outcomes in patients who had CTP mismatch compared with those who did not, suggesting a benefit for prognosis (see the Evaluation for Prognosis section).

Second, Rai et al (2013) evaluated rates of recanalization and functional outcomes in a cohort of 99 patients selected by CTP for treatment with endovascular stroke therapy and compared results with historical controls from the MERCI [Mechanical Embolus Removal in Cerebral Ischemia], Multi-MERCI, and Penumbra device trials that treated all comers.¹⁶ Patients were included if they had anterior circulation symptoms at presentation with a baseline NIHSS score of 8 or greater and intracerebral vascular occlusion on admission CTA correlating with the neurologic deficit. There was no cutoff time for treatment, and the type of endovascular therapy was thrombolytics in 33 (33.3%), the mechanical device only in 24 (24.2%), and both treatments in 42 (42.4%). Successful recanalization was achieved in 55.6%, with a good outcome in 41.4% of patients. The recanalization rate in this study did not differ significantly from the 46% for MERCI and 68% for Multi-MERCI but was significantly lower than the 82% recanalization rate in the Penumbra device trial. In patients successfully recanalized, good outcomes were obtained in 67% in this study compared with 46% in MERCI, 49% in Multi-MERCI, and 29% in Penumbra. The

rate of futile recanalization (defined as a poor outcome despite successful recanalization) was 33% in Rai et al (2013) compared with 54% in MERCI, 51% in Multi-MERCI, and 71% for Penumbra.

Further, real-world experience from a high-volume center in the Czech Republic using the automated CTP imaging analysis processing software (RAPID) to select patients for thrombectomy raises questions about the applicability of findings from RCTs of CTP imaging in everyday clinical practice.¹⁷ In the EXTEND-IA RCT⁹ - in which thrombectomy was initiated within a median of 210 minutes post-stroke - rates of 90-day mRS score of 0-2 were 71%. In contrast, in everyday clinical practice at the Czech Republic center, despite a similar median time from stroke to reperfusion of 230 minutes, rates of 90-day mRS score of 0-2 were much lower at 37%. The authors of the Czech Republic study suggested this may have been due to the somewhat smaller ischemic cores and penumbras in their patients, but noted that many other factors that can vary in real-life clinical practice may also play a role (e.g., level/time of successful reperfusion, localization of core and penumbra).¹⁷

Cohort Studies

Results of the CT Perfusion to Predict Response to Recanalization in Ischemic Stroke Project study were published by Lansberg et al (2017).¹⁸ This study was a multicenter cohort study of 190 acute stroke patients assessed by CTP prior to endovascular therapy, although the decision to proceed with endovascular therapy (stent retrievers, manual aspiration, intra-arterial thrombolytic agents, and/or angioplasty with or without stenting, depending on the operator's preference) was not dependent on the CTP results (automated analysis with RAPID software). Patients up to 18 hours after symptom onset were included. Patients with target mismatch (n=131) had higher odds of a favorable clinical response based on the NIHSS (83% vs 44%; p=0.002; adjusted OR, 6.6; 95% CI, 2.1 to 20.9).

A single-center retrospective cohort study by De Mueynck et al (2020) evaluated functional outcomes following introduction of CTP as a selection tool for thrombectomy compared with historical data from a similar local retrospective study.¹⁹ Among patients with acute ischemic stroke who underwent thrombectomy and provided evaluable data, there was no significant difference between CTP-guided selection (n=76) and historical controls (n=65) at 90 days in good functional outcome (mRS score of 0-2; 48.4% versus 44%, respectively; p = 1.0), excellent functional outcome (mRS score of 0-1; 34.4% versus 29%; p = 1.0), and significant ICH (4.1% versus 5%; p = not reported).

Subsection Summary: Evaluation for Mechanical Embolectomy

CTP imaging is one of the several approaches used in acute stroke to better define viable ischemic tissue and identify patients who might benefit from mechanical endovascular intervention. RCTs have shown improved outcomes with mechanical embolectomy when patients were selected based on CTP imaging within 6 hours,⁹ at 6 to 16 hours,¹⁰ and at 6 to 24 hours,¹¹ supporting the use of CTP for evaluation for mechanical embolectomy. Other RCTs have used time from stroke onset, multiphase CTA, and Alberta Stroke Program Early CT Score as selection criteria. CTP may be considered an effective method to determine suitability for mechanical embolectomy.

Evaluation for Prognosis

Investigators from the Dutch Acute Stroke Trial (DUST; 2017) evaluated prediction models with NCCT, CTA, or CTP at baseline and day 3 to predict outcomes at 90 days.²⁰ A total of 224 patients from the DUST trial were selected who had anterior circulation occlusion on CTA with an ischemic deficit on CTP at admission and also had follow-up imaging on day 3. An unfavorable outcome (mRS score of 3-6) at 90 days was identified in 44% of patients. For models that included baseline variables plus 1 of the 3 imaging modalities on day 3, the area under the receiver operating characteristics curve was 0.85 for NCCT, 0.86 for CTA, and 0.86 for CTP. All 3 models improved prediction compared with no imaging on day 3 but there was no difference between the models. CTP at day 3 was no better than NCCT in predicting the clinical outcome.

A prognostic model, developed with data from DUST, was reported by van Seeters et al (2015).²¹ The authors analyzed an unselected population of 1374 patients with suspected anterior circulation stroke who underwent multimodal CT. Images were evaluated by an observer blinded to all clinical information except for the side of stroke symptoms. The analysis used 60% of patients for a prediction model and 40% for a validation cohort. Poor outcome (90-day mRS score, 3-6) occurred in 501 (36.5%) patients. Included in the basic prediction model were patient characteristics (age, stroke severity, time from onset to imaging, dependency before stroke symptoms, glucose level, whether the treatment had been given) and NCCT measures. CTA and CTP imaging also were predictive of clinical outcome. However, adding CTA and CTP imaging to the basic prediction model did not improve prediction. For example, in the validation cohort, the area under the curve was 0.78 (95% CI, 0.73 to 0.82) when using patient characteristics and NCCT. When CTA and CTP imaging were added to the model, the area under the curve was 0.79 (95% CI, 0.75 to 0.83).

Borst et al (2015), discussed above, reported on the relation between CTP imaging-derived parameters and functional outcomes from the MR CLEAN trial.¹⁵ Functional outcome as measured by mRS score at 90 days was associated with the CTP imaging-derived ischemic core volume (OR, 0.79 per 10 mL; 95% CI, 0.73 to 0.87 per 10 mL; $p < 0.001$) and percentage ischemic core (OR, 0.82 per 10%; 95% CI, 0.66 to 0.99 per 10%; $p = 0.002$), but not the penumbra. This trial population had been selected for treatment using mechanical embolectomy.

Subsection Summary: Evaluation of Prognosis

Retrospective analyses of data from the MR CLEAN and DUST trials found that the ischemic core detected on CTP imaging was predictive of functional outcomes. However, analysis of data from the DUST study found no improvement in a prediction model when CTP imaging was added to a basic model that used only patient characteristics and NCCT. CTP at day 3 did not outperform NCCT for stroke prognosis.

Subarachnoid Hemorrhage and Cerebral Vasospasm

Clinical Context and Test Purpose

The purpose of CTP imaging in patients with SAH is to evaluate those at high risk for vasospasm or delayed cerebral ischemia and to improve treatment decisions.

The question addressed in this evidence review is: Does the use of CTP improve the net health outcome of patients with aneurysmal SAH?

The following PICO was used to select literature to inform this review.

Patients

The relevant population of interest is patients with SAH who are being evaluated for vasospasm or delayed cerebral ischemia.

Interventions

The intervention of interest is CTP imaging as an add-on to NCCT.

Comparators

The following practice is currently being used to make decisions about managing SAH: standard management without CTP.

Outcomes

The outcomes of interest are function, as measured with NIHSS or mRS scores at 90 days after aneurysmal SAH.

Technically Reliable

Assessment of technical reliability focuses on specific tests and operators and requires a review of unpublished and often proprietary information. Review of specific tests, operators, and

unpublished data are outside the scope of this evidence review and alternative sources exist. This evidence review focuses on the clinical validity and clinical utility.

Clinically Valid

A test must detect the presence or absence of a condition, the risk of developing a condition in the future, or treatment response (beneficial or adverse).

Cerebral Ischemia

Meta-analyses

A meta-analysis by Greenberg et al (2010) assessed the diagnostic accuracy of CTA and CTP for cerebral vasospasm identified 3 studies (total n=64 patients) that met the inclusion criteria and contained data appropriate for statistical analysis.²² In these studies, "vasospasm" was defined on CTP as a perfusion deficit demonstrating prolonged mean transit time and decreased cerebral blood flow (CBF). However, there were no standardized thresholds for mean transit time or CBF to determine vasospasm, contributing to the heterogeneity among these studies. For this meta-analysis, "angiographic vasospasm" was defined as evidence of arterial narrowing compared with the parent vessel or with a baseline examination; symptomatic and asymptomatic patients were included. Compared with digital subtraction angiography, CTP pooled estimates had 74% sensitivity and 93% specificity.

Cohort studies

The pattern of sensitivity and specificity with CTP were similar in a retrospective study by Stecco et al (2018) (70% and 100%, respectively). Stecco et al evaluated 19 patients selected for a combined CTA and CTP approach based on clinical signs of arterial vasospasm and positive transcranial Doppler.²³ However, given the small sample sizes and the heterogeneity of the CTP imaging data, these results should be considered preliminary.

Sanelli et al (2011) also retrospectively studied the development of vasospasm in 75 patients with the aneurysmal SAH who had a CTP imaging assessment (there was likely overlap in subjects with the study described above).²⁴ Based on a multistage reference standard, 28 (37%) patients were classified using vasospasm. CTP imaging values (CBF, mean transit time) on days 0 to 3 were significantly lower in the vasospasm group. Optimal thresholds were then determined for CBF (50% sensitivity, 91% specificity), mean transit time (61% sensitivity, 70% specificity), and cerebral blood volume (CBV) (36% sensitivity, 89% specificity). Clinical outcomes of the vasospasm group included 15 (54%) patients with no permanent neurologic deficit, 11 (39%) with permanent neurologic deficit, and 2 (7%) who died during hospitalization.

Delayed Cerebral Ischemia

Meta-analyses

A systematic review and meta-analysis by Cremers et al (2014) included 11 studies (total n=570 patients) on the use of CTP to identify delayed cerebral ischemia.²⁵ CTP imaging measures at admission did not differ between patients who did and did not develop delayed cerebral ischemia. Some measures of CTP (CBF and mean transit time but not CBV) differed between groups during the 4 to 14 days after SAH, suggesting a possible role in diagnosis of delayed cerebral ischemia.

A meta-analysis by Sun et al (2019) evaluated the use of CTP to identify patients at risk for delayed cerebral ischemia in the acute phase (<4 days) after aneurysmal SAH.²⁶ The meta-analysis included 3 studies (total n=128 patients), 2 of which were included in the meta-analysis by Cremers et al (2014). The authors reported that patients with positive CTP in the acute phase were significantly more likely to develop delayed cerebral ischemia (OR, 32.15; 95% CI, 9.92–104.21).

Cohort Studies

One study included in the Cremers et al (2014) meta-analysis is the prospective study by Sanelli et al (2011) of 97 patients that evaluated the accuracy of CTP imaging to diagnose delayed

cerebral ischemia following aneurysmal SAH.²⁷ CTP imaging was performed between days 6 and 8 in asymptomatic patients and on the day of clinical deterioration in symptomatic patients. Perfusion maps were qualitatively evaluated by 2 neuroradiologists, both blinded to clinical and imaging data, and compared with the reference standard. Based on a multistage hierarchical reference standard that incorporated both imaging and clinical criteria, 40 (41%) patients were diagnosed with delayed cerebral ischemia. Overall diagnostic accuracy for CTP, determined from receiver operating characteristic curves, was 93% for CBF, 88% for mean transit time, and 72% for CBV. The study also sought to determine a quantitative threshold for delayed cerebral ischemia with CTP imaging, although it was noted that absolute thresholds might not be generalizable due to differences in scanner equipment and postprocessing methods. Clinical outcomes of the delayed cerebral ischemia group included 19 (48%) patients with no permanent neurologic deficit, 16 (40%) with permanent neurologic deficit, and 5 (13%) who died during hospitalization.

A retrospective cohort study by Starnoni et al (2019) of 38 patients with aneurysmal SAH evaluated CTP within 48 hours after hemorrhage.²⁸ The occurrence of DCI was significantly correlated with lower mean early CBF values ($p = 0.049$) and vasospasm with lower mean CBF ($p = 0.01$) and mean transit time ($p < 0.00001$) values. Mean transit time threshold values of 5.5 seconds were shown to have 94% specificity and 100% sensitivity for predicting the risk of developing vasospasm.

Section Summary: Subarachnoid Hemorrhage and Cerebral Vasospasm

One prospective study has shown a qualitative measure of CBF to have 93% accuracy for the detection of delayed cerebral ischemia, with lower accuracy for CBV. No studies identified provided evidence of a change in management leading to improved function following CTP imaging. Further study is needed to evaluate whether CTP in patients with aneurysmal SAH leads to the early identification of patients at high risk for vasospasm or delayed cerebral ischemia, alters treatment decisions, and improves health outcomes.

Brain Tumors

Clinical Context and Test Purpose

The purpose of CTP imaging in patients with brain tumors is grading gliomas. Potential uses are to guide biopsy and to monitor low-grade gliomas.

The question addressed in this evidence review is: Does the use of CTP improve the net health outcome of patients with brain tumors?

The following PICO was used to select literature to inform this review.

Patients

The relevant population of interest is patients with gliomas.

Interventions

The intervention of interest is CTP imaging as an add-on to NCCT.

Comparators

The following practice is currently being used to make decisions about managing brain tumors: standard management without CTP.

Outcomes

The outcome of interest is glioma grade.

Technically Reliable

Assessment of technical reliability focuses on specific tests and operators and requires a review of unpublished and often proprietary information. Review of specific tests, operators, and

unpublished data are outside the scope of this evidence review and alternative sources exist. This evidence review focuses on the clinical validity and clinical utility.

Clinically Valid

A test must detect the presence or absence of a condition, the risk of developing a condition in the future, or treatment response (beneficial or adverse).

Xyda et al (2011) reported on a prospective study of the feasibility and efficacy of volume perfusion computed tomography (VPCT) for the preoperative assessment of suspected cerebral gliomas in 46 consecutive patients.²⁹ (Whereas typical CTP imaging covers a relatively narrow range of brain tissue, the VPCT system with multispiral acquisition covers the entire tumor.) Two blinded readers independently evaluated VPCT by drawing volumes of interest around the tumor according to maximum intensity projection volumes. The volumes of interest were mapped onto the CBV, CBF, and permeability perfusion datasets, which correspond to histopathologic microvascular density. VPCT was followed by stereotactic biopsy or surgery to evaluate the histopathology of the tumor and classified into a low grade (I-II) and high grade (III-IV). The diagnostic power of the perfusion parameters was assessed using receiver operating characteristic curve analysis. Permeability demonstrated the highest diagnostic accuracy (97% sensitivity, 100% specificity), positive predictive value (100%), and negative predictive value (94%) to identify or exclude high-grade tumors.

A review by Jain (2011) indicated that most of the literature on the utility of perfusion imaging for glioma grading is based on various magnetic resonance perfusion techniques.³⁰ A study by Ellika et al (2007) compared CTP imaging with conventional MRI in 19 patients.³¹ With a cutoff point of greater than 1.92 normalized CBV, there was a sensitivity of 85.7% and a specificity of 100% to differentiate high-grade gliomas. There were no significant differences in normalized CBV between grade III and IV tumors. A subsequent study by Jain et al (2008) correlated CTP imaging findings with histopathologic grade in 32 patients with astroglial tumors.³² Eight additional patients with oligodendrogliomas were excluded from analysis because of the known higher blood volume compared with astroglial tumors. Of the 32 patients included in the study, 8 had low-grade gliomas, and 24 had high-grade gliomas. In this select set of patients, CTP imaging showed significant differences in grade III and IV tumors.

Section Summary: Brain Tumors

For indications such as brain tumors, data on CTP imaging are limited. One study assessed the diagnostic accuracy of CTP imaging to differentiate between high-grade and low-grade gliomas. Prospective studies in an appropriate patient population are needed to evaluate the sensitivity and specificity of CTP glioma grading, with a histopathologic assessment of tumors as the independent reference standard. One prospective study performed receiver operating characteristic analysis to evaluate the diagnostic accuracy of VPCT. This is the first report using VPCT to differentiate gliomas; therefore, replication of these findings in an independent sample is needed. Consistency in the thresholds used is also needed. Studies are also needed to show an improvement in health outcomes following the use of CTP imaging. No recent reports on the use of CTP imaging for the evaluation of brain tumors were identified.

Summary of Evidence

Acute Stroke

For individuals who have acute stroke who are being evaluated for thrombolysis who receive CTP imaging, the evidence includes a systematic review with meta-analysis, a randomized controlled trial (RCT), and cohort studies. Relevant outcomes are overall survival (OS), test accuracy, symptoms, morbid events, and functional outcomes. One potential area of benefit is greater individualization of therapy for acute stroke by better defining at-risk ischemic areas that may benefit from thrombolysis. Evidence from nonrandomized comparative studies has suggested that outcomes after thrombolysis are better in patients who have target mismatch on perfusion imaging than in patients without target mismatch and that patients with target mismatch treated after a 3 hour time window have outcomes similar to patients treated within 3

hours. However, the therapeutic changes that would be associated with identifying specific target mismatch pattern on CTP are not well-defined. Additionally, although available evidence from the RCT suggests some modest benefit for acute stroke patients who receive CTP or magnetic resonance imaging and receive alteplase up to 9 hours post-stroke, the overall net health outcome is unclear because there was also a lack of significant benefit on the secondary outcome of functional improvement and a trend toward increased risk of symptomatic intracranial hemorrhage and there were important limitations in relevance and potential limitations in statistical power. Therefore, RCTs are needed to determine with greater certainty whether a strategy employing CTP imaging improves health outcomes compared with traditional strategies for the treatment of acute stroke. The evidence is insufficient to determine the effects of the technology on health outcomes.

For individuals who have acute anterior large-vessel stroke who are being evaluated for mechanical embolectomy who receive CTP imaging, the evidence includes RCTs and cohort studies. Relevant outcomes are OS, test accuracy, symptoms, morbid events, and functional outcomes. CTP is one of the several approaches used in acute stroke to define viable ischemic tissue better and therefore identify patients who might benefit from mechanical endovascular intervention. Alternative methods of patient selection for mechanical embolectomy have included time from stroke onset, multiphase computed tomography angiography, or Alberta Stroke Program Early CT Score. Three RCTs showed improved outcomes with mechanical embolectomy when patients were selected based on CTP results within 6 hours, at 6 to 16 hours, and at 6 to 24 hours. The evidence is sufficient to determine that the technology results in a meaningful improvement in the net health outcome.

For individuals who have acute stroke who are being evaluated for prognosis who receive CTP imaging, the evidence includes retrospective analyses of large, randomized trials. Relevant outcomes are OS, test accuracy, symptoms, morbid events, and functional outcomes. Retrospective analysis of data from the MR CLEAN and DUST trials have found that the ischemic core detected on CTP imaging was predictive of functional outcomes. However, analysis of data from the DUST study found no improvement in a prediction model when CTP imaging was added to a basic model that used only patient characteristics and non-contrast computed tomography. The evidence is insufficient to determine the effects of the technology on health outcomes.

Subarachnoid Hemorrhage

For individuals who have SAH and cerebral vasospasm who receive CTP imaging, the evidence includes a systematic review with meta-analysis and a cohort study. Relevant outcomes are OS, test accuracy, symptoms, morbid events, and functional outcomes. CTP imaging is being evaluated for the diagnosis of vasospasm and delayed cerebral ischemia following aneurysmal SAH. One prospective study showed a qualitative measure of cerebral blood flow to have 93% accuracy for the detection of delayed cerebral ischemia, with lower accuracy for cerebral blood volume. Prospective trials are needed to determine whether CTP imaging in patients with aneurysmal SAH leads to the early identification of patients at high-risk for vasospasm or delayed cerebral ischemia, alters treatment decisions, and improves health outcomes. The evidence is insufficient to determine the effects of the technology on health outcomes.

Brain Tumors

For individuals who have brain tumors who receive CTP imaging, the evidence includes studies on diagnostic accuracy. Relevant outcomes are test accuracy, symptoms, morbid events, and functional outcomes. For indications such as brain tumors and head trauma, the data on CTP imaging is limited. One study assessed the diagnostic accuracy of CTP imaging to differentiate high-grade from low-grade gliomas. Prospective studies in an appropriate population of patients are needed to evaluate the sensitivity and specificity of CTP glioma grading, with a histopathologic assessment of tumors as the independent reference standard. One prospective study performed a receiver operating characteristic curve analysis to evaluate the diagnostic accuracy of volume perfusion computed tomography. This is the first report using volume

perfusion computed tomography to differentiate gliomas; therefore, replication of these findings in an independent sample of patients is needed as well as clarification of the clinical utility of this information. Studies showing the consistency in the thresholds used are needed, as are studies showing improvement in health outcomes with CTP imaging. No recent reports on the use of CTP imaging for the evaluation of brain tumors have been identified. The evidence is insufficient to determine the effects of the technology on health outcomes.

Supplemental Information

Clinical Input From Physician Specialty Societies and Academic Medical Centers

While the various physician specialty societies and academic medical centers may collaborate with and make recommendations during this process, through the provision of appropriate reviewers, input received does not represent an endorsement or position statement by the physician specialty societies or academic medical centers, unless otherwise noted.

In response to requests from Blue Cross Blue Shield Association, input was received from 4 physician specialty societies (8 reviewers) and 3 academic medical centers in 2012. Most inputs supported some uses of computed tomography perfusion (CTP) imaging; however, there was little consensus on specific indications that would be considered medically necessary. For use in late stroke, most reviewers agreed that CTP imaging could identify patients with late stroke who may benefit from thrombolysis, but there was no consensus whether the benefits of using this strategy to select patients with late stroke for thrombolysis outweighed the risks. Some additional indications recommended by reviewers included differential diagnosis, e.g., excluding stroke mimics, determination of stroke subtype, determination of stroke extent, identification of patients at high early risk for debilitating stroke following transient ischemic attack, determining the need for blood pressure management, guiding disposition decisions such as the need for intensive care unit placement, and establishing prognosis. Evaluation of chronic cerebral ischemia and head trauma were also noted as potential indications. There was near consensus that CTP imaging is investigational for head trauma and for the staging and management of brain tumors.

Practice Guidelines and Position Statements

American Heart Association and American Stroke Association

The American Heart Association (AHA) and American Stroke Association (ASA; 2012) joint guidelines on the management of aneurysmal subarachnoid hemorrhage recommended that perfusion imaging with computed tomography or magnetic resonance can be useful to identify regions of potential brain ischemia (class IIa; level of evidence B). The guidelines stated there are emerging data that perfusion imaging, demonstrating regions of hypoperfusion, may be more accurate for identifying delayed cerebral ischemia than anatomic imaging of arterial narrowing or changes in blood flow velocity by transcranial Doppler. The guidelines concluded that CTP imaging is a promising technology, although repeat measurements are limited by the risks of dye load and radiation exposure.

The AHA and ASA (2013) guidelines on the early management of adults with ischemic stroke recommended that CTP, magnetic resonance perfusion, and diffusion imaging, including measures of infarct core and penumbra, may be considered for selecting a patient for acute reperfusion therapy beyond intravenous fibrinolytic time windows.³³ The guidelines stated these techniques provide additional information that may improve diagnosis, mechanism, and severity of the ischemic stroke and permit more informed clinical decision making (class IIb, level of evidence B).

The AHA and ASA (2019) revised their 2018 guideline statement on the use of CTP for the early management of adults with ischemic stroke.³⁴ Table 3 summarizes the new recommendations that were made.

Table 3. New Guidelines Recommendations on Use of Computed Tomography Perfusion

Recommendation	SOR	LOB	LOE
In patients eligible for IV alteplase, because benefit of therapy is time dependent, treatment should be initiated as quickly as possible and not delayed for additional multimodal neuroimaging, such as CT and MRI perfusion imaging.	I	Strong benefit	B-NR (nonrandomized)
When selecting patients with AIS within 6 to 24 hours of last known normal who have large vessel occlusion in the anterior circulation, obtaining CTP or DW-MRI, with or without MRI perfusion, is recommended to aid in patient selection for mechanical thrombectomy, but only when patients meet other eligibility criteria from one of the RCTs that showed benefit from mechanical thrombectomy in this extended time window.	I	Strong benefit	A (high-quality evidence from multiple RCTs)
In selected patients with acute ischemic stroke (> 16-24 hours of last normal) and large vessel occlusion, DAWN criteria (which may include imaging findings from CTP) may be used for clinical decision making regarding mechanical thrombectomy	Ila	Moderate benefit	B-R (nonrandomized)

CT: computed tomography; CTP: computed tomography perfusion; DW-MRI: diffusion-weighted magnetic resonance imaging; IV: intravenous; LO B: level of benefit; LOE: level of evidence; MRI: magnetic resonance imaging; RCT: randomized controlled trial; SOR : strength of recommendation.

American Society of Neuroradiology et al

The American Society of Neuroradiology, the American College of Radiology (ACR), and the Society of NeuroInterventional Surgery (2013) issued a joint statement on imaging recommendations for acute stroke and transient ischemic attack.³⁵ The following statements were made on perfusion imaging:

- "In acute stroke patients who are candidates for endovascular therapy, vascular imaging (CTA [computed tomography angiography], MRA [magnetic resonance angiography], DSA [digital subtraction angiography]) is strongly recommended during the initial imaging evaluation. Perfusion imaging may be considered to assess the target tissue 'at risk' for reperfusion therapy. However, the accuracy and usefulness of perfusion imaging to identify and differentiate viable tissue have not been well-established."
- "Determination of tissue viability based on imaging has the potential to individualize thrombolytic therapy and extend the therapeutic time window for some acute stroke patients. Although perfusion imaging has been incorporated into acute stroke imaging algorithms at some institutions, its clinical utility has not been proved."
- "It is important to note that perfusion imaging has many applications beyond characterization of the penumbra and triage of patients to acute revascularization therapy.... These applications include, but are not limited to, the following: 1) improving the sensitivity and accuracy of stroke diagnosis (in some cases, a lesion on PCT [perfusion-CT] leads to more careful scrutiny and identification of a vascular occlusion that was not evident prospectively, particularly in the M2 and more distal MCA [middle cerebral artery] branches); 2) excluding stroke mimics; 3) better assessment of the ischemic core and collateral flow; and 4) prediction of hemorrhagic transformation and malignant edema."

The American Society of Neuroradiology, the Society for Pediatric Radiology, and ACR (2017) revised their joint practice parameters on the performance of CTP in neuroradiologic imaging.³⁶ The primary indications for CTP imaging of the brain were described as acute neurologic change suspicious for stroke, suspected vasospasm following subarachnoid hemorrhage, and cerebral hemorrhage with secondary local ischemia. Secondary indications included follow-up of acute cerebral ischemia or infarction, to assist in planning and evaluating therapy effectiveness, in patients with a contraindication to magnetic resonance imaging, in the setting of acute traumatic brain injury, and intracranial tumors. There was "little data" to support the role of brain CTP imaging in pediatric stroke.

American College of Radiology

The ACR Appropriateness Criteria, updated in 2016, have provided the following ratings for head CTP imaging with contrast (see Table 4).³⁷

Table 4. Appropriateness of Head Computed Tomography Perfusion Imaging With Contrast

Recommendation	Rating
For asymptomatic individuals with a structural lesion on physical examination (cervical bruit) and/or risk factors	5
If directly employed in decision making and planning treatment for carotid territory or vertebrobasilar transient ischemic attack on the initial screening survey	5
For a new focal neurologic defect, fixed or worsening; less than 6 hours	6
For a new focal neurologic defect, fixed or worsening; longer than 6 hours	5
For evaluation for cerebral vasospasm after aneurysmal subarachnoid hemorrhage	5

Rating scale: 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate.

The ACR also noted that computed tomography stroke protocols combining a brain noncontrast computed tomography, computed tomography angiography, and CTP might produce a relative radiation level of 1 to 10 mSv, and repeated use of this protocol in an individual patient might result in high radiation exposure to the scalp and eyes.

U.S. Preventive Services Task Force Recommendations

Not applicable.

Medicare National Coverage

There is no national coverage determination. In the absence of a national coverage determination, coverage decisions are left to the discretion of local Medicare carriers.

Ongoing and Unpublished Clinical Trials

Some currently ongoing and unpublished trials that might influence this review are listed in Table 5.

Table 5. Summary of Key Trials

NCT No.	Trial Name	Planned Enrollment	Completion Date
<i>Ongoing</i>			
NCT01387113	Expanding the Time Window for IV Thrombolysis With Rt-PA in Acute Ischemic Stroke Patients Using Computed Tomography Perfusion Imaging: The PERFusion Use in Stroke Evaluation (PERFUSE) Study	100	Jan 2021
<i>Unpublished</i>			
NCT01923922	CT perfusion in the Prognostication of Cerebral High Grade Glioma	100	Dec 2017 (unknown)
NCT02360670	Penumbra and Recanalisation Acute Computed Tomography in Ischaemic Stroke Evaluation	400	Nov 2018

NCT: national clinical trial.

References

1. Bivard A, Levi C, Krishnamurthy V, et al. Perfusion computed tomography to assist decision making for stroke thrombolysis. *Brain*. Jul 2015; 138(Pt 7): 1919-31. PMID 25808369
2. Schaefer PW, Souza L, Kamalian S, et al. Limited reliability of computed tomographic perfusion acute infarct volume measurements compared with diffusion-weighted imaging in anterior circulation stroke. *Stroke*. Feb 2015; 46(2): 419-24. PMID 25550366
3. Liebeskind DS, Parsons MW, Wintermark M, et al. Computed Tomography Perfusion in Acute Ischemic Stroke: Is It Ready for Prime Time?. *Stroke*. Aug 2015; 46(8): 2364-7. PMID 26159791

4. Burton KR, Dhanoa D, Aviv RI, et al. Perfusion CT for selecting patients with acute ischemic stroke for intravenous thrombolytic therapy. *Radiology*. Jan 2015; 274(1): 103-14. PMID 25243539
5. Ma H, Campbell BCV, Parsons MW, et al. Thrombolysis Guided by Perfusion Imaging up to 9 Hours after Onset of Stroke. *N Engl J Med*. May 09 2019; 380(19): 1795-1803. PMID 31067369
6. Garcia-Bermejo P, Calleja AI, Perez-Fernandez S, et al. Perfusion computed tomography-guided intravenous thrombolysis for acute ischemic stroke beyond 4.5 hours: a case-control study. *Cerebrovasc Dis*. 2012; 34(1): 31-7. PMID 22759450
7. Sztrihai LK, Manawadu D, Jarosz J, et al. Safety and clinical outcome of thrombolysis in ischaemic stroke using a perfusion CT mismatch between 3 and 6 hours. *PLoS ONE*. 2011; 6(10): e25796. PMID 22016775
8. Medina-Rodriguez M, Millan-Vazquez M, Zapata-Arriaza E, et al. Intravenous Thrombolysis Guided by Perfusion CT with Alteplase in 4.5 Hours from Stroke Onset. *Cerebrovasc Dis*. 2020; 49(3): 328-333. PMID 32615572
9. Campbell BC, Mitchell PJ, Kleinig TJ, et al. Endovascular therapy for ischemic stroke with perfusion-imaging selection. *N Engl J Med*. Mar 12 2015; 372(11): 1009-18. PMID 25671797
10. Albers GW, Marks MP, Kemp S, et al. Thrombectomy for Stroke at 6 to 16 Hours with Selection by Perfusion Imaging. *N Engl J Med*. Feb 22 2018; 378(8): 708-718. PMID 29364767
11. Nogueira RG, Jadhav AP, Haussen DC, et al. Thrombectomy 6 to 24 Hours after Stroke with a Mismatch between Deficit and Infarct. *N Engl J Med*. Jan 04 2018; 378(1): 11-21. PMID 29129157
12. Berkhemer OA, Fransen PS, Beumer D, et al. A randomized trial of intraarterial treatment for acute ischemic stroke. *N Engl J Med*. Jan 01 2015; 372(1): 11-20. PMID 25517348
13. Goyal M, Demchuk AM, Menon BK, et al. Randomized assessment of rapid endovascular treatment of ischemic stroke. *N Engl J Med*. Mar 12 2015; 372(11): 1019-30. PMID 25671798
14. 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. *Int J Stroke*. Apr 2015; 10(3): 439-48. PMID 25777831
15. Borst J, Berkhemer OA, Roos YB, et al. Value of Computed Tomographic Perfusion-Based Patient Selection for Intra-Arterial Acute Ischemic Stroke Treatment. *Stroke*. Dec 2015; 46(12): 3375-82. PMID 26542698
16. Rai AT, Raghuram K, Domico J, et al. Pre-intervention triage incorporating perfusion imaging improves outcomes in patients undergoing endovascular stroke therapy: a comparison with the device trials. *J Neurointerv Surg*. Mar 2013; 5(2): 121-7. PMID 22345110
17. Vanicek J, Cimflova P, Bulik M, et al. Single-Centre Experience with Patients Selection for Mechanical Thrombectomy Based on Automated Computed Tomography Perfusion Analysis-A Comparison with Computed TomographyCT Perfusion Thrombectomy Trials. *J Stroke Cerebrovasc Dis*. Apr 2019; 28(4): 1085-1092. PMID 30655040
18. Lansberg MG, Christensen S, Kemp S, et al. Computed tomographic perfusion to Predict Response to Recanalization in ischemic stroke. *Ann Neurol*. Jun 2017; 81(6): 849-856. PMID 28486789
19. De Muynck E, Huybrechts V, Hemelsoet D, et al. CT Perfusion as a Selection Tool for Mechanical Thrombectomy, a Single-Centre Study. *J Belg Soc Radiol*. Jan 20 2020; 104(1): 3. PMID 31998861
20. Dankbaar JW, Horsch AD, van den Hoven AF, et al. Prediction of Clinical Outcome After Acute Ischemic Stroke: The Value of Repeated Noncontrast Computed Tomography, Computed Tomographic Angiography, and Computed Tomographic Perfusion. *Stroke*. Sep 2017; 48(9): 2593-2596. PMID 28716981
21. van Seeters T, Biessels GJ, Kappelle LJ, et al. The Prognostic Value of CT Angiography and CT Perfusion in Acute Ischemic Stroke. *Cerebrovasc Dis*. 2015; 40(5-6): 258-69. PMID 26484857

22. Greenberg ED, Gold R, Reichman M, et al. Diagnostic accuracy of CT angiography and CT perfusion for cerebral vasospasm: a meta-analysis. *AJNR Am J Neuroradiol*. Nov 2010; 31(10): 1853-60. PMID 20884748
23. Stecco A, Fabbiano F, Amatuzzo P, et al. Computed tomography perfusion and computed tomography angiography in vasospasm after subarachnoid hemorrhage. *J Neurosurg Sci*. Aug 2018; 62(4): 397-405. PMID 27124176
24. Sanelli PC, Jou A, Gold R, et al. Using CT perfusion during the early baseline period in aneurysmal subarachnoid hemorrhage to assess for development of vasospasm. *Neuroradiology*. Jun 2011; 53(6): 425-34. PMID 20694461
25. Cremers CH, van der Schaaf IC, Wensink E, et al. CT perfusion and delayed cerebral ischemia in aneurysmal subarachnoid hemorrhage: a systematic review and meta-analysis. *J Cereb Blood Flow Metab*. Feb 2014; 34(2): 200-7. PMID 24281744
26. Sun H, Ma J, Liu Y, et al. CT Perfusion for Identification of Patients at Risk for Delayed Cerebral Ischemia during the Acute Phase after Aneurysmal Subarachnoid Hemorrhage: A Meta-analysis. *Neurol India*. Sep-Oct 2019; 67(5): 1235-1239. PMID 31744949
27. Sanelli PC, Ugorec I, Johnson CE, et al. Using quantitative CT perfusion for evaluation of delayed cerebral ischemia following aneurysmal subarachnoid hemorrhage. *AJNR Am J Neuroradiol*. Dec 2011; 32(11): 2047-53. PMID 21960495
28. Starnoni D, Maduri R, Hajdu SD, et al. Early Perfusion Computed Tomography Scan for Prediction of Vasospasm and Delayed Cerebral Ischemia After Aneurysmal Subarachnoid Hemorrhage. *World Neurosurg*. Oct 2019; 130: e743-e752. PMID 31284055
29. Xyda A, Haberland U, Klotz E, et al. Brain volume perfusion CT performed with 128-detector row CT system in patients with cerebral gliomas: a feasibility study. *Eur Radiol*. Sep 2011; 21(9): 1811-9. PMID 21573969
30. Jain R. Perfusion CT imaging of brain tumors: an overview. *AJNR Am J Neuroradiol*. Oct 2011; 32(9): 1570-7. PMID 21051510
31. Ellika SK, Jain R, Patel SC, et al. Role of perfusion CT in glioma grading and comparison with conventional MR imaging features. *AJNR Am J Neuroradiol*. Nov-Dec 2007; 28(10): 1981-7. PMID 17893216
32. Jain R, Ellika SK, Scarpace L, et al. Quantitative estimation of permeability surface-area product in astroglial brain tumors using perfusion CT and correlation with histopathologic grade. *AJNR Am J Neuroradiol*. Apr 2008; 29(4): 694-700. PMID 18202239
33. Jauch EC, Saver JL, Adams HP, et al. Guidelines for the early management of patients with acute ischemic stroke: a guideline for healthcare professionals from the American Heart Association/American Stroke Association. *Stroke*. Mar 2013; 44(3): 870-947. PMID 23370205
34. 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. *Stroke*. Dec 2019; 50(12): e344-e418. PMID 31662037
35. Wintermark M, Sanelli PC, Albers GW, et al. Imaging recommendations for acute stroke and transient ischemic attack patients: A joint statement by the American Society of Neuroradiology, the American College of Radiology, and the Society of NeuroInterventional Surgery. *AJNR Am J Neuroradiol*. Nov-Dec 2013; 34(11): E117-27. PMID 23907247
36. American College of Radiology, American Society of Neuroradiology, Society for Pediatric Radiology. ACR- ASNR-SPR practice parameter for the performance of computed tomography (CT) perfusion in neuroradiologic imaging. 2017; <https://www.acr.org/-/media/ACR/Files/Practice-Parameters/ct-perfusion.pdf?la=en>. Accessed July 22, 2020.
37. American College of Radiology (ACR). ACR Appropriateness Criteria: Cerebrovascular Disease. 2016; <https://acsearch.acr.org/docs/69478/Narrative/>. Accessed July 22, 2020.
38. Blue Cross Blue Shield Association. Medical Policy Reference Manual, No. 6.01.49 (September 2020).

Documentation for Clinical Review

Please provide the following documentation:

- History and physical and/or consultation notes
- Reason for CT perfusion imaging

Post Service (in addition to the above, please include the following):

- CT Imaging report

Coding

This Policy relates only to the services or supplies described herein. Benefits may vary according to product design; therefore, contract language should be reviewed before applying the terms of the Policy. Inclusion or exclusion of codes does not constitute or imply member coverage or provider reimbursement.

Type	Code	Description
CPT®	0042T	Cerebral perfusion analysis using computed tomography with contrast administration, including post-processing of parametric maps with determination of cerebral blood flow, cerebral blood volume, and mean transit time
HCPCS	None	

Policy History

This section provides a chronological history of the activities, updates and changes that have occurred with this Medical Policy.

Effective Date	Action
06/28/2007	BCBSA Medical Policy adoption
10/01/2010	Policy Revision with title change from CT (Computed Tomography) Cerebral Perfusion Imaging
08/23/2013	Title change from Computed Tomography Perfusion Imaging and policy revision without position change. Policy placed on No Further Routine Literature Review and Update status.
10/31/2014	Policy revision with no position change
12/04/2015	Policy title change from Computed Tomography (CT) Perfusion Imaging of the Brain Policy revision with position change
12/01/2016	Policy revision without position change
11/01/2017	Policy revision without position change
11/01/2018	Policy revision without position change
12/01/2019	Policy revision without position change
11/01/2020	Annual review. No change to policy statement. Literature review updated.

Definitions of Decision Determinations

Medically Necessary: Services that are Medically Necessary include only those which have been established as safe and effective, are furnished under generally accepted professional standards to treat illness, injury or medical condition, and which, as determined by Blue Shield, are: (a) consistent with Blue Shield medical policy; (b) consistent with the symptoms or diagnosis; (c) not furnished primarily for the convenience of the patient, the attending Physician or other provider; (d) furnished at the most appropriate level which can be provided safely and

effectively to the patient; and (e) not more costly than an alternative service or sequence of services at least as likely to produce equivalent therapeutic or diagnostic results as to the diagnosis or treatment of the Member's illness, injury, or disease.

Investigational/Experimental: A treatment, procedure, or drug is investigational when it has not been recognized as safe and effective for use in treating the particular condition in accordance with generally accepted professional medical standards. This includes services where approval by the federal or state governmental is required prior to use, but has not yet been granted.

Split Evaluation: Blue Shield of California/Blue Shield of California Life & Health Insurance Company (Blue Shield) policy review can result in a split evaluation, where a treatment, procedure, or drug will be considered to be investigational for certain indications or conditions, but will be deemed safe and effective for other indications or conditions, and therefore potentially medically necessary in those instances.

Prior Authorization Requirements (as applicable to your plan)

Within five days before the actual date of service, the provider must confirm with Blue Shield that the member's health plan coverage is still in effect. Blue Shield reserves the right to revoke an authorization prior to services being rendered based on cancellation of the member's eligibility. Final determination of benefits will be made after review of the claim for limitations or exclusions.

Questions regarding the applicability of this policy should be directed to the Prior Authorization Department at (800) 541-6652, or the Transplant Case Management Department at (800) 637-2066 ext. 3507708 or visit the provider portal at www.blueshieldca.com/provider.

Disclaimer: This medical policy is a guide in evaluating the medical necessity of a particular service or treatment. Blue Shield of California may consider published peer-reviewed scientific literature, national guidelines, and local standards of practice in developing its medical policy. Federal and state law, as well as contract language, including definitions and specific contract provisions/exclusions, take precedence over medical policy and must be considered first in determining covered services. Member contracts may differ in their benefits. Blue Shield reserves the right to review and update policies as appropriate.