**Policy Statement**

Intracranial stent placement may be considered *medically necessary* as part of the endovascular treatment of intracranial aneurysms for patients when all of the following criteria are met:

- Surgical treatment is not appropriate
- Standard endovascular techniques do not allow for complete isolation of the aneurysm, e.g., wide-neck aneurysm (greater than or equal to 4 millimeters [mm]) or a sack-to-neck ratio less than 2 to 1

Intracranial flow-diverting stents with U.S. Food and Drug Administration (FDA) approval for the treatment of intracranial aneurysms may be considered *medically necessary* as part of the endovascular treatment of intracranial aneurysms that meet anatomic criteria (see Policy Guidelines section) and are not amenable to surgical treatment or standard endovascular therapy.

Intracranial stent placement is considered *investigational* in the treatment of intracranial aneurysms except as noted above.

Intracranial percutaneous transluminal angioplasty with or without stenting is considered *investigational* in the treatment of atherosclerotic cerebrovascular disease.

The use of endovascular mechanical embolectomy using a device with FDA approval for the treatment of acute ischemic stroke may be considered *medically necessary* as part of the treatment of acute ischemic stroke for patients who meet all of the following criteria:

- Have a demonstrated occlusion within the proximal intracranial anterior circulation (intracranial internal carotid artery, or M1 or M2 segments of the middle cerebral artery, or A1 or A2 segments of the anterior cerebral artery)
- Can receive endovascular mechanical embolectomy within 12 hours of symptom onset OR within 24 hours of symptom onset if there is evidence of a mismatch between specific clinical and imaging criteria (see Policy Guidelines)
- Have evidence of substantial and clinically significant neurologic deficits (see Policy Guidelines section)
- Have evidence of salvageable brain tissue in the affected vascular territory (see Policy Guidelines section)
- Have no evidence of intracranial hemorrhage or arterial dissection on computed tomography (CT) or magnetic resonance imaging (MRI)

Endovascular interventions are considered *investigational* for the treatment of acute ischemic stroke when the above criteria are not met.

**Policy Guidelines**

**Patient Selection for Endovascular Mechanical Embolectomy for Acute Ischemic Stroke**

The major randomized controlled trials (RCTs) demonstrating a benefit with endovascular mechanical embolectomy vary in criteria for selecting patients based on the presence or absence of salvageable brain tissue. Several RCTs use the Alberta Stroke Program Early Computed Tomography Score (ASPECTS), which is a 10-point quantitative computed tomography (CT) score to assess the presence of early ischemic changes. The Multicenter Randomized Clinical trial of Endovascular treatment for Acute ischemic stroke in the Netherlands (MR CLEAN) trial found that patients with a score of 5 or higher had a greater chance of receiving clinical benefit from mechanical embolectomy.
(MR CLEAN) (Berkhemer et al, 2015) did not specify imaging criteria to demonstrate salvageable brain tissue. Table PG1 lists the criteria used by other trials.

**Table PG1. Trial Selection Criteria for Salvageable Brain Tissue**

<table>
<thead>
<tr>
<th>Trial</th>
<th>Inclusion or Exclusion</th>
<th>Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>REVASCAT (Jovin et al, 2015)</td>
<td>Exclusion</td>
<td>Hypodensity on CT or restricted diffusion demonstrated by:</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- An ASPECTS less than 7 on CT, CT perfusion CBV, CTA source imaging; OR</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- An ASPECTS less than 6 on DWI MRI</td>
</tr>
<tr>
<td>ESCAPE (Goyal et al, 2015)</td>
<td>Exclusion</td>
<td>- Baseline non-contrast CT with extensive early ischemic changes of ASPECTS of 0 to 5 in the territory of symptomatic intracranial occlusion; OR</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Other confirmation of a moderate-to-large core defined 1 of 3 ways:</td>
</tr>
<tr>
<td></td>
<td></td>
<td>o On a single phase, multiphase, or dynamic CTA: no or minimal collaterals in a region greater than 50% of the MCA territory when compared with pial filling on the contralateral side (multiphase/dynamic CTA preferred); OR</td>
</tr>
<tr>
<td></td>
<td></td>
<td>o On CT perfusion (greater than 8 cm coverage): a low CBV and very low CBF, ASPECTS less than 6 AND in the symptomatic MCA territory; OR</td>
</tr>
<tr>
<td></td>
<td></td>
<td>o On CT perfusion (less than 8 cm coverage): a region of low CBV and very low CBF greater than one-third of the CT perfusion-imaged symptomatic MCA territory</td>
</tr>
<tr>
<td>EXTEND-IA (Campbell et al, 2015)</td>
<td>Inclusion</td>
<td>Based on CT perfusion imaging using CT or MRI with a Tmax more than 6-second delay perfusion volume and either CT regional CBF or DWI infarct core volume as follows:</td>
</tr>
<tr>
<td></td>
<td></td>
<td>-Mismatch ratio greater than 1.2; AND</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Absolute mismatch volume greater than 10 mL; AND</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Infarct core lesion volume less than 10 ml</td>
</tr>
<tr>
<td>SWIFT-PRIME (Saver et al, 2015)</td>
<td>Exclusion</td>
<td>Related to imaging-demonstrated core infarct and hypoperfusion:</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- MRI-assessed core infarct lesion greater than:</td>
</tr>
<tr>
<td></td>
<td></td>
<td>o 50 cm³ for subjects age 18 to 79 years</td>
</tr>
<tr>
<td></td>
<td></td>
<td>o 20 cm³ for subjects age 80 to 85 years</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- CT-assessed core infarct lesion greater than:</td>
</tr>
<tr>
<td></td>
<td></td>
<td>o 40 cm³ for subjects age 18 to 79 years</td>
</tr>
<tr>
<td></td>
<td></td>
<td>o 15 cm³ for subjects age 80 to 85 years</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- For all subjects, severe hypoperfusion lesion (greater than or equal to 10-second Tmax lesion larger than 100 cm³)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- For all subjects, ischemic penumbra of 15 cm³ or more and mismatch ratio greater than 1.8</td>
</tr>
</tbody>
</table>

ASPECTS: Alberta Stroke Program Early Computed Tomography Score; CBF: cerebral blood flow; CBV: cerebral blood volume; CT: computed tomography; CTA: computed tomography angiography; DWI: diffusion-weighted imaging; MCA: middle cerebral artery; MRI: magnetic resonance imaging; ESCAPE: Endovascular Treatment for Small Core and Proximal Occlusion Ischemic Stroke; EXTEND-IA: Extending the Time for Thrombolysis in Emergency Neurological Deficits - Intra-Arterial; REVASCAT: Endovascular Revascularization With Solitaire Device Versus Best Medical Therapy in Anterior Circulation Stroke Within 8 Hours; SWIFTPRIME: Solitaire™ With the Intention For Thrombectomy as PRIMary Endovascular Treatment

The RCTs demonstrating a benefit to endovascular mechanical embolectomy in acute stroke generally had some inclusion criteria to reflect stroke severity with the exception of the Extending the Time for Thrombolysis in Emergency Neurological Deficits - Intra-Arterial (EXTEND-IA) trial. The Endovascular Revascularization With Solitaire Device Versus Best Medical Therapy in Anterior Circulation Stroke Within 8 Hours (REVASCAT) and Endovascular Treatment for Small Core and Proximal Occlusion Ischemic Stroke (ESCAPE) trials both required a baseline (poststroke) National Institutes of Health Stroke Scale (NIHSS) score of 6 or higher. MR CLEAN
specified a clinical diagnosis of acute stroke with a deficit on the NIHSS score of 2 points or more; Solitaire™ With the Intention For Thrombectomy as PRIMary Endovascular Treatment (SWIFT-PRIME) specified an NIHSS score of 8 or more and less than 30 at the time of randomization.

The Clinical Mismatch in the Triage of Wake Up and Late Presenting Strokes Undergoing Neurointervention With Trevo (DAWN) and Endovascular Therapy Following Imaging Evaluation for Ischemic Stroke 3 (DEFUSE 3) studies enrolled patients from 6 up to 24 hours of the time last known to be well if there was evidence of a mismatch between specific clinical and imaging criteria (infarct size and volume was assessed with the use of diffusion-weighted magnetic resonance imaging or perfusion CT) (see Table PG2).

### Table PG2. Trial Selection Criteria for Patients 6 to 25 Hours Post Infarct

<table>
<thead>
<tr>
<th>Trial</th>
<th>Inclusion or Exclusion</th>
<th>Criteria</th>
</tr>
</thead>
</table>
| **DAWN Trial** *(Nogueira et al, 2018)* | **Inclusion**          | 6 to 24 hours related to mismatch between severity of clinical deficit and infarct volume:  
• Greater than or equal to 80 years of age, score greater than or equal to 10 on the NIHSS, and had an infarct volume less than 21 mL; OR  
• Less than or equal to 80 years of age, score of greater than or equal to 10 on the NIHSS, and had an infarct volume less than 31 mL; OR  
• Less than or equal to 80 years of age, had a score greater than or equal to 20 on the NIHSS, and had an infarct volume of 31 to less than 51 mL |
| **DEFUSE 3 Trial** *(Albers et al, 2018)* | **Inclusion**          | 6 to 16 hours related to mismatch between severity of clinical deficit and infarct volume:  
• Infarct size of less than 70 mL; AND  
• Ratio of ischemic tissue volume to infarct volume of greater than or equal to 1.8; AND  
• Ischemic penumbra of greater than or equal to 15 cm³ |

NIHSS: National Institutes of Health Stroke Scale; DAWN: Clinical Mismatch in the Triage of Wake Up and Late Presenting Strokes Undergoing Neurointervention With Trevo®; DEFUSE 3: Endovascular Therapy Following Imaging Evaluation for Ischemic Stroke 3.

**Other Policy Guidelines**

Flow-diverting stents are indicated for the treatment of large or giant wide-necked intracranial aneurysms, with a size of 10 mm or more and a neck diameter of 4 mm or more, in the internal carotid artery from the petrous to the superior hypophyseal segments.

This policy only addresses endovascular therapies used on intracranial vessels.

These policy statements are not intended to address the use of rescue endovascular therapies, including intra-arterial vasodilator infusion and intracranial percutaneous transluminal angiography, in delayed cerebral ischemia after aneurysmal subarachnoid hemorrhage.

**Coding**

There are specific CPT codes for intracranial angioplasty and stent placement:

- **61630**: Balloon angioplasty, intracranial (e.g., atherosclerotic stenosis), percutaneous
- **61635**: Transcatheter placement of intravascular stent(s), intracranial (e.g., atherosclerotic stenosis), including balloon angioplasty, if performed

**Note**: Codes 61630 and 61635 include all selective vascular catheterization of the target vascular family, all diagnostic imaging for arteriography of the target vascular family, and all related radiologic supervision and interpretation. If a diagnostic arteriogram confirmed the need for angioplasty or stent placement, those services are also included in 61630 and 61635.
There is a specific CPT code for mechanical thrombectomy:

- **61645**: Percutaneous arterial transluminal mechanical thrombectomy and/or infusion for thrombolysis, intracranial, any method, including diagnostic angiography, fluoroscopic guidance, catheter placement, and intra procedural pharmacological thrombolytic injection(s)

### Description

Intracranial arterial disease includes thromboembolic events, vascular stenoses, and aneurysms. Endovascular techniques have been investigated for the treatment of intracranial arterial disease. Endovascular therapy is used as an alternative or adjunct to intravenous tissue plasminogen activator and supportive care for acute stenosis and as an adjunct to risk-factor modification for chronic stenosis. For cerebral aneurysms, stent-assisted coiling and the use of flow-diverting stents have been evaluated as an alternative to endovascular coiling in patients whose anatomy is not amenable to simple coiling.

### Related Policies

- Extracranial Carotid Artery Stenting

### 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 devices for endovascular treatment of intracranial arterial disease were cleared for marketing by the U.S. Food and Drug Administration (FDA) through the 510(k) process or the humanitarian device exemption process. By indication, approved devices are as follows.

#### Acute Stroke

Table 1 summarizes the first generation devices with the FDA clearance for the endovascular treatment of acute stroke and subsequent approval of stent retrievers.

**Table 1. FDA-Cleared Mechanical Embolectomy Devices for Acute Stroke**

<table>
<thead>
<tr>
<th>Device</th>
<th>510(k) No. for Original Device</th>
<th>Approval Date for Original Device</th>
<th>Indications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Merci® Retriever (Concentric Medical; acquired by Stryker Neurovascular in 2011)</td>
<td>K033736</td>
<td>Aug 2004 (modified device approved May 2006)</td>
<td>Patients with acute ischemic stroke and who are ineligible for or who fail IV tPA therapy</td>
</tr>
<tr>
<td>Penumbra System® (Penumbra)</td>
<td>K072718</td>
<td>Dec 2007</td>
<td>Patients with acute ischemic stroke secondary to intracranial large vessel</td>
</tr>
</tbody>
</table>
Device | 510(k) No. for Original Device | Approval Date for Original Device | Indications |
--- | --- | --- | --- |
Stent retrievers | | | occlusive disease within 8 h of symptom onset |
Solitaire™ FR Revascularization Device (Covidien/ev3 Neurovascular) | K113455 | Mar 2012 | Patients with acute ischemic stroke due to large intracranial vessel occlusion who are ineligible for or who fail IV tPA |
Trevo® Retriever device (Stryker Neurovascular) | K122478 | Aug 2012 | Patients with acute ischemic stroke due to large intracranial vessel occlusion who are ineligible for or who fail IV tPA |
EmboTrap® II Revascularization Device | K173452 | May 2018 | Patients with ischemic stroke within 8 hours of symptom onset who are ineligible for or who fail IV t-PA |

FDA: Food and Drug Administration; IV: intravenous; tPA: tissue plasminogen activator.

**Intracranial Arterial Stenosis**

Two devices were approved by the FDA through the humanitarian device exemption process for atherosclerotic disease. This form of the FDA approval is available for devices used to treat conditions with an incident rate of 4000 or fewer cases per year; the FDA only requires data showing “probable safety and effectiveness.” Devices with their labeled indications are as follows.

**Neurolink System®**

“The Neurolink system® [Guidant] is indicated for the treatment of patients with recurrent intracranial stroke attributable to atherosclerotic disease refractory to medical therapy in intracranial vessels ranging from 2.5 to 4.5 mm in diameter with ≥ 50% stenosis and that are accessible to the stent system.”

**Wingspan™ Stent System**

“The Wingspan™ Stent System [Boston Scientific] with Gateway PTA [percutaneous transluminal angioplasty] Balloon Catheter is indicated for use in improving cerebral artery lumen diameter in patients with intracranial atherosclerotic disease, refractory to medical therapy, in intracranial vessels with ≥ 50% stenosis that are accessible to the system.”

**Intracranial Aneurysms**

In 2011, the Pipeline® Embolization Device (Covidien/eV3 Neurovascular), an intracranial aneurysm flow-diverter, was approved by the FDA through the premarket approval process (P100018) for the endovascular treatment of adults (≥ 22 years) with large or giant wide-necked intracranial aneurysms in the internal carotid artery from the petrous to the superior hypophyseal segments. Approval was based on the Pipeline® for Uncollapsible for Failed Aneurysms Study, a single-arm, open-label feasibility study, reported by Becske et al (2013) that included 108 patients, ages 30 to 75 years, with unruptured large and giant wide-necked aneurysms.

In 2018, Surpass Streamline Flow Diverter (Stryker Neurovascular) was approved by the FDA through the premarket approval process (P170024) for use in the endovascular treatment of patients (18 years of age and older) with unruptured large or giant saccular wide-neck (neck width ≥ 4 mm or dome-to-neck ratio < 2) or fusiform intracranial aneurysms in the internal carotid artery from the petrous segment to the terminus arising from a parent vessel with a diameter ≥ 2.5 mm and ≤ 5.3 mm. The approval was based on 1 year results of the Surpass Intracranial Aneurysm Embolization System Pivotal Trial to Treat Large or Giant Wide Neck Aneurysms (SCENT)
The following stents have been approved by the FDA through the humanitarian device exemption process for treatment of intracranial aneurysms.

**Neuroform™ Microdelivery Stent System**
In 2002, based on a series of approximately 30 patients with 6-month follow-up, the Neuroform™ Microdelivery Stent System (Stryker) was approved by the FDA through the humanitarian device exemption process (H020002) for use with embolic coils for the treatment of wide-neck intracranial aneurysms that cannot be treated by surgical clipping.

**Neuroform™ Atlas Stent System**
In 2019, the Neuroform™ Atlas Stent System (Stryker) was approved by the FDA through the PMA process (P190031) based on the pivotal ATLAS study including 201 patients with up to 12 months of follow-up. The approved indication is for use with neurovascular embolization coils in the anterior circulation of the neurovasculature for the endovascular treatment of patients greater or equal to 18 years of age with saccular wide-necked (neck width greater or equal to 4 mm or a dome-to-neck ratio of < 2) intracranial aneurysms arising from a parent vessel with a diameter of greater or equal to 2.0 mm and less than or equal to 4.5 mm. “Product Code: QCA.”

**Enterprise™ Vascular Reconstruction Device and Delivery System**
In 2007, based on a series of approximately 30 patients with 6-month follow-up, the Enterprise™ Vascular Reconstruction Device and Delivery (Cordis Neurovascular) was approved by the FDA through the humanitarian device exemption process (H060001) for use with embolic coils for the treatment of wide-neck, intracranial, saccular or fusiform aneurysms.

**The Low-Profile Visualized Intraluminal Support Device**
In 2014, the Low-Profile Visualized Intraluminal Support Device (LVIS™ and LVIS™ Jr.; MicroVention) was approved by the FDA through the humanitarian device exemption process (H130005) for use with embolic coils for the treatment of unruptured, wide-neck (neck, ≥4 mm or dome-to-neck ratio, <2), intracranial, saccular aneurysms arising from a parent vessel with a diameter of 2.5 mm or greater and 4.5 mm or smaller. In 2018, the LVIS™ and LVIS™ Jr. were approved through the PMA process (P170013).

**PulseRider Aneurysm Neck Reconstruction Device**
In 2017, the PulseRider Aneurysm Neck Reconstruction Device (Pulsar Vascular, Inc.) was approved by the FDA through the humanitarian device exemption process (H160002) for use with neurovascular embolic coils for treatment of unruptured wide-necked intracranial aneurysms with neck width at least 4 mm or dome to neck ratio greater than 2.

## Rationale

### Background

**Cerebrovascular Diseases**
Cerebrovascular diseases include a range of processes affecting the cerebral vascular system, including arterial thromboembolism, arterial stenosis, and arterial aneurysms, all of which can restrict cerebral blood flow due to ischemia or hemorrhage. Endovascular techniques, including endovascular mechanical embolectomy with various devices types of devices (i.e., stents), and angioplasty with or without stenting have been investigated for the treatment of cerebrovascular diseases.

**Acute Stroke**
Acute stroke is the third leading cause of death in the United States, Canada, Europe, and Japan; further, it is the leading cause of adult disability in the United States. Eighty-seven percent of strokes are ischemic and 13% hemorrhagic. Differentiation between the 2 types of
stroke is necessary to determine the appropriate treatment. Ischemic stroke occurs when an artery to the brain is blocked by a blood clot, which forms in the artery (thrombotic), or when another substance (i.e., plaque, fatty material) travels to an artery in the brain causing a blockage (embolism). Recanalization of the artery, particularly in the first few hours after occlusion, reduces rates of disability and death.8

**Intracranial Arterial Stenosis**

It is estimated that intracranial atherosclerosis causes about 8% of all ischemic strokes. Intracranial stenosis may contribute to stroke in two ways: either due to embolism or low-flow ischemia in the absence of collateral circulation. Recurrent annual stroke rates are estimated at 4% to 12% per year with atherosclerosis of the intracranial anterior circulation and 2.5% to 15% per year with lesions of the posterior (vertebrobasilar) circulation.

**Intracranial Aneurysms**

Compared with acute ischemic stroke, cerebral aneurysms have a much lower incidence in the United States, with prevalence between 0.5% and 6% of the population.9 However, they are associated with significant morbidity and mortality due to subarachnoid hemorrhage resulting from aneurysm rupture.

**Literature Review**

Evidence reviews assess the clinical evidence to determine whether the use of technology improves the net health outcome. Broadly defined, health outcomes are the length of life, quality of life, and ability to function, including benefits and harms. Every clinical condition has specific outcomes that are important to patients and to managing the course of that condition. Validated outcome measures are necessary to ascertain whether a condition improves or worsens; and whether the magnitude of that change is clinically significant. The net health outcome is a balance of benefits and harms.

To assess whether the evidence is sufficient to draw conclusions about the net health outcome of technology, two domains are examined: the relevance, and quality and credibility. To be relevant, studies must represent one or more intended clinical use of the technology in the intended population and compare an effective and appropriate alternative at a comparable intensity. For some conditions, the alternative will be supportive care or surveillance. The quality and credibility of the evidence depend on study design and conduct, minimizing bias and confounding that can generate incorrect findings. The randomized controlled trial (RCT) is preferred to assess efficacy; however, in some circumstances, nonrandomized studies may be adequate. RCTs are rarely large enough or long enough to capture less common adverse events and long-term effects. Other types of studies can be used for these purposes and to assess generalizability to broader clinical populations and settings of clinical practice.

**Endovascular Interventions for Acute Ischemic Stroke**

**Clinical Context and Therapy Purpose**

The purpose of endovascular interventions in patients experiencing acute ischemic stroke is to remove thrombus and restore blood flow in a timely manner to salvage brain tissue that is not infarcted. The intervention must be performed as quickly as possible during the narrow window during which reperfusion is beneficial.

The question addressed in this evidence review is: Do endovascular therapies improve the net health outcome in patients with acute ischemic stroke?

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

**Patients**

The relevant population of interest is patients with a acute ischemic stroke caused by an intracranial large artery occlusion in the proximal anterior circulation who can be treated within a
Patients experiencing stroke symptoms may be seen in primary or emergency care. Most hospitals are able to treat acute ischemic stroke with intravenous alteplase; however, transfer to a tertiary stroke center may be necessary for patients who are eligible for endovascular mechanical embolectomy.

Interventions

Endovascular embolectomy devices remove or disrupt clots by a number of mechanisms. Several devices have the U.S. Food and Drug Administration (FDA) approval for treatment of acute stroke (see Regulatory Status section). The first-generation devices were the Merci® Retriever, and Penumbra System®. The second-generation devices included stent retrievers: Solitaire Flow Restoration Device, and the Trevo® Retriever. With the Merci® device, a micro-catheter is passed through the thrombus from a larger, percutaneous catheter positioned proxima to the occlusion. A helical snare is deployed, and the catheter and clot are withdrawn together. With the Penumbra device, an opening at the tip of the percutaneous catheter uses suction to extract the clot. Both the Solitaire Flow Restoration Device and the Trevo® Retriever are retrievable stents, which are positioned to integrate the clot with the stent for removal with the stent’s struts. Recently the EmboTrap® Revascularization Device (Neuravi Ltd.) was cleared with the Solitaire and Trevo® as predicate devices.

This evidence review focuses on the devices listed above with an indication for endovascular embolectomy for acute stroke. Additional retrievable stent devices are under investigation, such as the Embolus Retriever with Interlinked Cages (MicroVention)\(^1\). An additional clinical situation in which endovascular therapies may be used in the treatment of acute ischemic stroke is in the setting of cerebral vasospasm following intracranial (sub-arachnoid) hemorrhage. Delayed cerebral ischemia occurs about 3 to 14 days after the acute bleed in about 30% of patients experiencing subarachnoid hemorrhage and is a significant contributor to morbidity and mortality in patients who survive the initial bleed. In cases refractory to medical measures, rescue invasive therapies including intra-arterial vasodilator infusion therapy (e.g., calcium channel blockers) and transluminal balloon angioplasty may be used.\(^1\) The mechanism of disease, patient population, and time course of therapy differ for delayed cerebral ischemia occurring after subarachnoid hemorrhage compared with ischemic stroke due to atheroembolic disease. Therefore, this indication for endovascular intervention is not addressed in this evidence review.

Comparators

The prompt use of intravenous (IV) thrombolytic therapy with recombinant tissue plasminogen activator (tPA) to recanalize occluded blood vessels has been associated with improved outcomes in multiple RCTs and meta-analyses.\(^9\) Therefore, use of IV tissue plasminogen activator (tPA) in ischemic stroke patients presenting within 3 hours (up to 4.5 hours in some cases) of stroke onset in expert centers is recommended.

Despite the potential benefits of IV tissue plasminogen activator (tPA) in eligible patients who present within the appropriate time window, limitations to reperfusion therapy with IV tPA have prompted investigations of alternative acute stroke therapies. These limitations include:

- **Requirement for treatment within 4.5 hours of stroke onset.** Relatively few patients present for care within the time window in which tPA has shown benefit. In addition, determining the time of onset of symptoms is challenging in patients awakening with symptoms of acute stroke; patients with symptoms on awakening are considered to have symptom onset when they went to sleep. In 2010 and 2011, fewer than 10% of all ischemic stroke patients arrived at the hospital and received IV tPA within the 3-hour window.\(^15\)
- **Risks associated with IV tPA therapy.** tPA is associated with increased risk of intracranial bleeding. It is contraindicated in hemorrhagic stroke and in some ischemic stroke
patients for whom the risk of bleeding outweighs the potential benefit, such as those with mild or resolving symptoms, hypocoagulable state, or advanced age.

- Variable recanalization rates. For patients receiving tPA, recanalization rates are around 21% and range from 4% in the distal internal carotid artery and basilar artery to 32% in the middle cerebral artery. The treatment of large vessel strokes with IV tPA may be less successful.

Researchers have studied intra-arterial tPA, transcranial ultrasound energy, and mechanical clot destruction or clot removal as alternatives or second lines to the established intravenous tPA therapy.

**Outcomes**

The relevant outcomes in studies that evaluate acute ischemic stroke treatment include overall survival, functional status (e.g., disability or disability-free survival), and quality of life. Intermediate outcomes may include the success of revascularization. Rates of treatment-related adverse effects, including vessel perforation, hemorrhage, or thrombus formation in a new site, are important safety outcomes.

Standardized, validated neurologic scales, disability measures, or handicap scales used in the evaluation of neurothrombectomy devices include the modified Rankin Scale, the National Institutes of Health Stroke Scale, the Barthel Index, or the Glasgow Outcome Scale.

The most commonly used instrument in studies assessed is the modified Rankin Scale, a clinician-reported measure of global disability. The modified Rankin Scale can be administered using a structured interview or checklist or clinician-directed. Scores of 0 to 2 indicate subjects have no to slight disability. The highest score, a 6, indicates death. The modified Rankin Scale has been well studied, including its test-retest reliability, interrater reliability, and validity (construct and convergent). The instrument's limitations include being subject to the negative effect of co-morbidities, which are common in stroke patients, as well as factors such as socioeconomic status and surgery.

Results pertaining to 3 specific outcomes are the focus here: the proportion of patients with 90-day modified Rankin Scale scores between 0 and 2, short-term mortality rates, and rates of symptomatic intracranial hemorrhage. The primary goal of rapid revascularization in acute stroke is to reduce rates of significant disability; modified Rankin Scale scores ranging from 0 to 2 correspond to functional independence, and so represent a clinically useful measure of disability. Prior studies of endovascular therapy and thrombolytic therapy for acute stroke have been associated with increased risks of symptomatic intracranial hemorrhage, so this is another important safety-related outcome to evaluate.

Another frequently used measure of neurologic impairment is the National Institutes of Health Stroke Scale, which is a clinician-administered 15-item scale that measures global impairment after a stroke, developed for use in acute stroke therapy trials. Higher scores refer to worse impairment. Functional status using the modified Rankin Scale and mortality will be evaluated at 90 days. Longer term mortality is also of interest.

**Selection criteria**

Studies were included that met the following criteria:

- Population consisting of adults with acute ischemic stroke.
- RCTs
- Studies comparing endovascular treatment with at least some patients receiving mechanical embolectomy, with or without IV tPA, to IV tPA alone or “standard medical care,” or studies comparing two mechanical embolectomy devices.
- Sample size of at least 50 subjects.
Endovascular Interventions for Anterior Circulation Acute Ischemic Strokes

Review of Evidence

Systematic Reviews

Multiple systematic reviews and meta-analyses of RCTs evaluating endovascular therapy for acute stroke have been published, with varying inclusion criteria. The most relevant systematic reviews include the results of a series of RCTs published after 2014 comparing endovascular therapies with standard care; they are the focus of this evidence review. Some systematic reviews have focused only on mechanical embolectomy, while others have evaluated endovascular therapies more broadly.

Badhiwala et al (2015) reported on results of a meta-analysis of RCTs evaluating mechanical embolectomy after acute ischemic stroke. Eligible studies were RCTs comparing endovascular therapy with standard care, including the use of IV tPA, in adults with acute stroke. Eight trials were included (Ciccone et al [2013], Kidwell et al [2013], Broderick et al [2013], Berkhemer et al [2015], Goyal et al [2015], Campbell et al [2015], Saver et al [2015], Jovin et al [2015]), with a total of 2423 patients. (These specific RCTs are described individually below.) Studies were assessed as having a low-risk of bias overall based on Cochrane criteria. In a meta-analysis, the use of endovascular intervention led to proportional treatment benefit across modified Rankin Scale scores (odds ratio [OR], 1.56; 95% confidence interval [CI], 1.14 to 2.13; p=0.005). Patients treated with endovascular intervention were more likely than standard care patients to have functional independence at 90 days (44.6% for endovascular treatment [95% CI, 36.6% to 52.8%] vs 31.8% for standard treatment [95% CI, 24.6% to 40.0%]), with an associated absolute risk difference of 12.0% (95% CI, 3.8% to 20.3%; OR=1.71; 95% CI, 1.18 to 2.49; p=0.005). However, there was significant heterogeneity (I²=75.4%) in the analysis of functional improvement outcomes. Reviewers conducted a number of sensitivity analyses around predictors of functional outcomes and found the following factors associated with functional outcomes:

- Use of angiographic imaging confirming proximal arterial occlusion (OR=2.24; 95% CI, 1.72 to 2.9; p<0.001 for interaction).
- Use of IV tPA and endovascular therapy (OR=2.07; 95% CI, 1.46 to 2.92; p=0.018 for interaction).
- Use of stent retriever for mechanical thrombectomy (OR=2.39; 95% CI, 1.88 to 3.04; p<0.001 for interaction).

There were no significant differences between endovascular intervention group and standard care group patients in rates of symptomatic intracranial hemorrhage or death at 90 days.

In a meta-analysis including the same 8 trials included in the Badhiwala et al (2015) study, Chen et al (2015) reported a similar odds for 90-day functional independence as Badhiwala.

Given the disproportionate benefit associated with stent retriever used in subgroup analyses of RCTs, there has been some focus on the specific efficacy of stent retrievers for acute stroke.

Bush et al (2016) conducted a meta-analysis of RCTs using predominantly stent retriever devices for acute stroke treatment. Trials that compared endovascular therapy using stent retrievers with medical management (defined as IV tPA unless it was contraindicated) were included. However, it was not specified how reviewers defined a threshold to determine whether stent retrievers were “predominantly” used. The analysis included 5 trials (Berkhemer et al [2015], Goyal et al [2015], Campbell et al [2015], Saver et al [2015], Jovin et al [2015]), with a total of 1287 patients. In pooled analysis for the review’s primary outcome (modified Rankin Scale scores at 90 days), patients randomized to endovascular therapy had odds for more favorable modified Rankin Scale score of 2.2 (95% CI, 1.66 to 2.98; p<0.001; I²=46.38%). Similar to the findings from the Badhiwala et al (2015) meta-analysis, there were no significant between-group differences in 90-day mortality rates or symptomatic intracranial hemorrhage rates.

Other related systematic reviews have reported similar results.
Randomized Controlled Trials

Endovascular Therapies vs Noninterventional Care

From 2012 to 2015, results from 8 large RCTs comparing endovascular therapies with the standard of care for acute ischemic stroke were published. Several additional trials that began enrolling patients around 2013 and 2014 were stopped early after the publication of trials during 2014 and 2015. Therefore, the sample sizes in the trials published after 2015 are much smaller than originally designed, and the power to detect clinically important differences is low. A high-level overview of the major RCTs follows, with summary results in Table 2. Subsequently, in this section, select trials are described in more detail.

Fourteen RCTs with a total of 3,061 patients (range, 70-656 patients) compared endovascular mechanical embolectomy with standard care for acute ischemic stroke. In 2 studies, the population and intervention delivered were not consistent with the target population and intervention; the remaining 12 studies with the populations and interventions of interest are the focus of this discussion. The most clinically relevant and consistently reported finding was a comparison between treatment and control groups in the proportion of patients with a modified Rankin Scale score between 0 and 2 at 90 days. Among the 12 studies reporting on the populations and interventions of interest, all provide some information on the proportion of patients with 90 day modified Rankin Scale scores of 0, 1, or 2. Across the studies, the absolute difference between treatment and control groups in the proportion of patients with 90-day functional independence ranged from 1.55% to 36%. Except MR Rescue (Mechanical Retrieval and Recanalization of Stroke Clots Using Embolectomy) (Kidwell et al [2013]19), all studies published before 2016 reported a statistically significant improvement in the proportion of patients with functional independence at 90 days, with ORs ranging from 1.7 to 3.8. Among the 6 studies published before 2016 reporting on the populations and interventions of interest, mortality rates and symptomatic intracranial hemorrhage rates did not differ significantly between study groups. It is not possible to draw conclusions about the safety or harm of the procedure from this finding; the lack of significant differences may be due to inadequate sample sizes. Among the studies published after 2015, most were stopped well before the originally planned sample size was enrolled because of benefit shown in earlier studies. Therefore, most studies published later do not have the power to detect clinically meaningful differences at the achieved sample size but are consistent in direction with the earlier studies.

Treatment Within Six to Eight Hours of Symptom Onset

REVASCAT (Endovascular Revascularization With Solitaire Device Versus Best Medical Therapy in Anterior Circulation Stroke Within 8 Hours) Trial. Jovin et al (2015) reported on results of the REVASCAT trial, which compared endovascular therapy using the Solitaire stent retriever device with medical therapy, including IV tPA when indicated, within 8 hours of stroke onset among 206 patients. Eligible patients had an occlusion of the proximal anterior circulation that could be treated within 8 hours of stroke onset, a prestroke modified Rankin Scale score of 0 to 1, and a baseline National Institutes of Health Stroke Scale score of at least 6 points (National Institutes of Health Stroke Scale score range, 0-42; higher scores associated with greater deficit). Intravenous tPA was administered before randomization. Patients were excluded if they had imaging-based evidence of a large ischemic core, indicated by an Alberta Stroke Program Early Computed Tomography Score (ASPECTS) of less than 7 on non-contrast computed tomography (CT) imaging or a score of less than 6 on diffusion-weighted magnetic resonance imaging. The trial was halted early for loss of equipoise given the results of the EXTEND-IA (Extending the Time for Thrombolysis in Emergency Neurological Deficits - Intra-Arterial), ESCAPE (Endovascular Treatment for Small Core and Proximal Occlusion Ischemic Stroke), and MR CLEAN (Multicenter Randomized Clinical trial of Endovascular Treatment for Acute Ischemic Stroke in the Netherlands) trials (described below) after the first planned interim analysis (when the first 25% of patients [n=174] reached 90 days of follow-up).

One hundred three patients were randomized to mechanical embolectomy, of whom 98 successfully underwent thrombectomy. Rates of tPA use between groups did not differ.
significantly (68.0% in the mechanical embolectomy group vs 77.7% in the control group). For the study’s primary outcome, the OR for improvement in the distribution of the modified Rankin Scale score was 1.7 (95% CI, 1.05 to 2.8), favoring mechanical embolectomy. A greater proportion of patients in the mechanical embolectomy group was functionally independent (modified Rankin Scale score, 0-2; 43.7% vs 28.2% in the control group; absolute risk difference, 15.5%; adjusted OR=2.1; 95% CI, 1.1 to 4.0). There were no significant differences between the mechanical embolectomy and the control groups in 90-day mortality (18.4% vs 15.5%; p=0.60) or 90-day rates of symptomatic intracranial hemorrhage (1.9% in each group; p=1.00).

### Table 2. Summary of Randomized Controlled Trials of Endovascular Therapy versus Standard Care

<table>
<thead>
<tr>
<th>Trial (Study)</th>
<th>Intervention</th>
<th>N</th>
<th>90-Day Modified Rankin Scale Score 0-2</th>
<th>Mortality</th>
<th>Symptomatic Intracranial Hemorrhage</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Per Group Rate, %</td>
<td>Between-Group Difference (95% CI)</td>
<td>Per Group Rate, %</td>
</tr>
<tr>
<td><strong>DEFUSE 3</strong></td>
<td>Intervention</td>
<td>92</td>
<td>45</td>
<td>OR=2.7 (1.6 to 4.5)</td>
<td>14</td>
</tr>
<tr>
<td>(Albers [2018])</td>
<td>Control</td>
<td>90</td>
<td>17</td>
<td></td>
<td>26</td>
</tr>
<tr>
<td></td>
<td>Intervention</td>
<td>107</td>
<td>49</td>
<td>ARR=36% (24% to 47%)</td>
<td>19</td>
</tr>
<tr>
<td><strong>DAWN</strong></td>
<td>Control</td>
<td>99</td>
<td>13</td>
<td></td>
<td>18</td>
</tr>
<tr>
<td>(Nogueira [2018])</td>
<td>Intervention</td>
<td>40a</td>
<td>50</td>
<td>p=0.36</td>
<td>28</td>
</tr>
<tr>
<td><strong>EASI</strong></td>
<td>Control</td>
<td>37a</td>
<td>38</td>
<td></td>
<td>24</td>
</tr>
<tr>
<td>(Khoury [2017])</td>
<td>Intervention</td>
<td>33a</td>
<td>51</td>
<td>OR=2.1 (0.7 to 6.9)</td>
<td>21</td>
</tr>
<tr>
<td><strong>PISTE</strong></td>
<td>Control</td>
<td>32a</td>
<td>40</td>
<td></td>
<td>13</td>
</tr>
<tr>
<td>(Muir [2017])</td>
<td>Intervention</td>
<td>55a</td>
<td>38</td>
<td>OR=1.4 (0.6 to 3.3)</td>
<td>12</td>
</tr>
<tr>
<td><strong>THERAPY</strong></td>
<td>Control</td>
<td>53a</td>
<td>30</td>
<td></td>
<td>24</td>
</tr>
<tr>
<td>(Mocco [2016])</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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<table>
<thead>
<tr>
<th>Trial (Study)</th>
<th>Intervention</th>
<th>N</th>
<th>90-Day Modified Rankin Scale Score 0-2</th>
<th>Mortality</th>
<th>Symptomatic Intracranial Hemorrhage</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Group</td>
<td></td>
<td>Per Group Rate, %</td>
<td>Between-Group Difference (95% CI)</td>
<td>Per Group Rate, %</td>
</tr>
<tr>
<td>THRACE</td>
<td>Intervention</td>
<td>202</td>
<td>53</td>
<td>OR=1.6 (1.1 to 2.3)</td>
<td>12</td>
</tr>
<tr>
<td>(Bracard [2016])</td>
<td>Control</td>
<td>200</td>
<td>42</td>
<td>13</td>
<td>2</td>
</tr>
<tr>
<td>REVASCAT</td>
<td>Intervention</td>
<td>103</td>
<td>43.7</td>
<td>ARR=15.5%</td>
<td>OR=2.1 (1.1 to 4.0)</td>
</tr>
<tr>
<td>(Jovin [2015])</td>
<td>Control</td>
<td>103</td>
<td>28.2</td>
<td>15.5</td>
<td>1.9</td>
</tr>
<tr>
<td>EXTEND-IA</td>
<td>Intervention</td>
<td>35</td>
<td>71</td>
<td>OR=3.8 (1.4 to 1.0)</td>
<td>20</td>
</tr>
<tr>
<td>(Campbell [2015])</td>
<td>Control</td>
<td>35</td>
<td>40</td>
<td>9</td>
<td>0</td>
</tr>
<tr>
<td>ESCAPE</td>
<td>Intervention</td>
<td>165</td>
<td>53</td>
<td>RR=1.8 (1.4 to 2.4)</td>
<td>10.4</td>
</tr>
<tr>
<td>(Goyal [2015])</td>
<td>Control</td>
<td>150</td>
<td>29.3</td>
<td>19.05</td>
<td></td>
</tr>
<tr>
<td>SWIFT-PRIME</td>
<td>Intervention</td>
<td>98</td>
<td>60</td>
<td>RR=0.74 (0.33 to 1.68)</td>
<td>0</td>
</tr>
<tr>
<td>(Saver [2015])</td>
<td>Control</td>
<td>98</td>
<td>35</td>
<td>12</td>
<td>3</td>
</tr>
<tr>
<td>MR CLEAN</td>
<td>Intervention</td>
<td>233</td>
<td>32.6</td>
<td>ARR=13.5%</td>
<td>OR=2.05 (1.36 to 3.09)</td>
</tr>
<tr>
<td>(Berkheimer [2015])</td>
<td>Control</td>
<td>267</td>
<td>19.1</td>
<td>18.4</td>
<td>6.4</td>
</tr>
<tr>
<td>MR RESCUE</td>
<td>Intervention</td>
<td>64</td>
<td>18.75</td>
<td>p=0.48</td>
<td>21</td>
</tr>
<tr>
<td>(Kidwell [2013])</td>
<td>Control</td>
<td></td>
<td></td>
<td></td>
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</tbody>
</table>
## 2.01.54 Endovascular Procedures for Intracranial Arterial Disease (Atherosclerosis and Aneurysms)

<table>
<thead>
<tr>
<th>Trial (Study)</th>
<th>Intervention</th>
<th>N</th>
<th>90-Day Modified Rankin Scale Score 0-2</th>
<th>Mortality</th>
<th>Symptomatic Intracranial Hemorrhage</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Group</td>
<td></td>
<td>Per Group Rate, %</td>
<td>Between-Group Difference (95% CI)</td>
<td>Per Group Rate, %</td>
</tr>
<tr>
<td>Control</td>
<td>Medical therapy (IV tPA if indicated)</td>
<td>54</td>
<td>20.3</td>
<td>21</td>
<td>4</td>
</tr>
<tr>
<td>SYNTHESIS EXP (Ciccone [2013])</td>
<td>Intervention</td>
<td>Intraarterial therapy w/wo IV tPA</td>
<td>181</td>
<td>30.4</td>
<td>OR=0.71 (0.44 to 1.14)</td>
</tr>
<tr>
<td>IMS III (Broderick [2013])</td>
<td>Intervention</td>
<td>Endovascular therapy + IV tPA</td>
<td>434</td>
<td>38.7</td>
<td>Adjusted difference: 1.5% (-6.1 to 9.1)</td>
</tr>
<tr>
<td>Control</td>
<td>IV tPA alone</td>
<td>181</td>
<td>34.8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td>IV tPA alone</td>
<td>222</td>
<td>40.8</td>
<td></td>
<td>21.6</td>
</tr>
</tbody>
</table>

ARR: absolute risk reduction; CI: confidence interval; IV: intravenous; OR: odds ratio; RR: relative risk; tPA: tissue plasminogen activator; w/wo: with/without; NS: not significant; NR: not reported.

**DAWN: Clinical Mismatch in the Triage of Wake Up and Late Presenting Strokes Undergoing Neurointervention With Trevo**;
**DEFUSE 3: Endovascular Therapy Following Imaging Evaluation for Ischemic Stroke 3**;
**EAS: Endovascular Acute Stroke Intervention**;
**ESCAPE: Endovascular Treatment for Small Core and Proximal Occlusion Ischemic Stroke**;
**EXTEND-IA: Extending the Time for Thrombolysis in Emergency Neurological Deficits - Intra-Arterial**;
**IMS III: Intervventional Management of Stroke III**;
**MR CLEAN: Multicenter Randomized Clinical trial of Endovascular Treatment for Acute Ischemic Stroke in the Netherlands**;
**MR RESCUE: Mechanical Retrieval and Recanalization of Stroke Clots Using Embolectomy**;
**PISTE: Pragmatic Ischemic Stroke Thrombectomy Evaluation**;
**REVASCAT: Endovascular Revascularization With Solitaire Device Versus Best Medical Therapy in Anterior Circulation Stroke Within 8 Hours**;
**SWIFT-PRIME: Solitaire ™ With the Intention For Thrombectomy as PrimarY Endovascular Treatment**;
**SYNTHESIS-EXP: Intra-arterial Versus Systemic Thrombolysis for Acute Ischemic Stroke**;
**THERAPY: Assess the Penumbra System® in the Treatment of Acute Stroke**;
**THRACE: Trial and Cost Effectiveness Evaluation of Intra-arterial Thrombectomy in Acute Ischemic Stroke.**

a Trial stopped early due to publication of results of other trials.
b Patients were enrolled in DEFUSE 3 and DAWN after the accepted window of time for which IV thrombolytic therapy is typically administered.

**EXTEND-IA (Extending the Time for Thrombolysis in Emergency Neurological Deficits - Intra-Arterial)**

Trial. Campbell et al (2015) reported on results of the EXTEND-IA trial comparing endovascular therapy with tPA alone. This trial enrolled patients with ischemic stroke who received IV tPA within 4.5 hours after stroke onset. Eligible patients had an occlusion of the internal carotid artery or M1 or M2 segments of the middle cerebral artery on computed tomography angiography and were able to receive endovascular therapy within six hours of stroke onset; further, the patients were functionally independent before the stroke. Patients were evaluated before enrollment with CT perfusion imaging and were required to have evidence of salvageable brain tissue and an ischemic core with a volume of less than 70 mL. CT perfusion imaging was analyzed with operator-independent postprocessing software. Enrollment was planned for 100 patients. The trial’s data safety and monitoring board reviewed data for the first 70 enrolled...
patients after the results of the MR CLEAN trial were published and stopped EXTEND-IA for efficacy based on prespecified criteria. The first 70 patients were randomized to IV tPA plus endovascular therapy using the Solitaire FR® retrievable stent (n=35) or no further therapy (IV tPA-only; n=35). The trial used 2 coprimary endpoints: reperfusion (measured as the percentage reduction in perfusion-lesion volume between the initial imaging and imaging at 24 hours) and early neurologic improvement (defined as a reduction of ≥8 points on the National Institutes of Health Stroke Scale or a score of 0 or 1 at day 3).

The demographics of the randomized groups were similar at baseline. About 25% of clinically eligible patients were excluded on the basis of perfusion imaging criteria. In the endovascular group, 8 (22.9%) of 35 patients did not undergo mechanical embolectomy, most commonly because most of the thrombus was lysed before angiography (n=4). Endovascular therapy subjects had increased reperfusion at 24 hours, with median reperfusion of 100% (percentage reduction in perfusion-lesion volume), compared with 37% for the tPA-only group (adjusted OR=4.7; 95% CI, 2.5 to 9.0; p<0.001). Of the endovascular therapy subjects, 28 (80%) of 35 had early neurologic improvement compared with 13 (37%) of 35 of the tPA-only subjects (adjusted OR=6.0; 95% CI, 2.0 to 18.0; p=0.02). Rates of reperfusion of at least 90% at 24 hours without symptomatic intracerebral hemorrhage were higher in endovascular therapy patients (89% vs 34% adjusted OR=27.0; 95% CI, 5.5 to 135.0; p<0.001). Safety outcomes, including death, symptomatic intracerebral hemorrhage, and parenchymal hematoma, did not differ significantly between groups.

ESCAPE (Endovascular Treatment for Small Core and Proximal Occlusion Ischemic Stroke) Trial. Goyal et al (2015) reported on results of the ESCAPE trial that compared endovascular therapy with guideline-based stroke care, including IV tPA if indicated. Patients with acute stroke were eligible if they presented within 12 hours of stroke onset, had a proximal intracranial occlusion in the anterior circulation, and had non-contrast CT or computed tomography angiography with the following findings: (1) small infarct core; (2) proximal artery occlusion, defined by occlusion of the middle cerebral artery trunk and its immediate branches, with or without intracranial occlusion of the internal carotid artery; and (3) moderate-to-good collateral circulation, defined as filling of 50% or more of the middle cerebral artery pial artery circulation on computed tomography angiography. A small infarct core was defined as a score of 6 to 10 on the ASPECTS, which is a 10-point scoring system designed to quantify the extent of ischemic changes in the middle cerebral artery territory. Patients received IV tPA if they met local guidelines. Patients were randomized to endovascular treatment (n=165), which could include any FDA approved stent retriever or aspiration device, balloon angioplasty, guidewire manipulation, and/or intra-arterial tPA, or guideline-based stroke care (n=150). Use of retrievable stents was recommended. Enrollment was planned for 316 subjects. The trial was stopped early on the advice of its data safety monitoring board, after an unplanned interim analysis following the publication of MR CLEAN trial results, because ESCAPE’s prespecified efficacy boundary had been crossed.

Of the 165 patients randomized to the intervention group, 151 (91.5%) underwent endovascular therapy, most commonly with a retrievable stent (130/151 [86.1%] of those who underwent an endovascular procedure), most often with the Solitaire stent (100/130 [77.0%] of those who received a retrievable stent). In the intervention group, 120 (72.7%) also received IV tPA. Of the 150 control group subjects, 118 (78.6%) received IV tPA. For the trial’s primary endpoint (90-day modified Rankin Scale score), compared with the control group, in the endovascular treatment group, the relative odds of improving 1 point on the modified Rankin Scale was 2.6 (95% CI, 1.7 to 3.8). Endovascular treatment group subjects compared with control group subjects also had lower 90 day modified Rankin Scale scores (median, 2 vs 4, respectively; p<0.001) and were more likely to have 90 day modified Rankin Scale scores of 0 to 2 (53% vs 29.3%; rate ratio, 1.8; 95% CI, 1.4 to 2.4; p<0.001). Ninety-day mortality was 10.4% among endovascular treatment group subjects and 19.0% in control group subjects (rate ratio, 0.5; 95% CI, 0.3 to 1.0; p=0.04).
SWIFT PRIME (Solitaire™ With the Intention For Thrombectomy as PRIMary Endovascular Treatment) Trial. Saver et al (2015) reported on results of the SWIFT PRIME trial comparing IV tPA followed by mechanical embolectomy using a stent retriever device with IV tPA alone in patients presenting with acute ischemic stroke. Eligible patients had moderate-to-severe neurologic deficits, imaging-confirmed occlusion of the intracranial internal carotid artery and/or the first segment of the middle cerebral artery, were receiving or had received IV tPA, and were able to undergo endovascular treatment within six hours of symptom onset. Also, eligible patients were required to have ischemic penumbral imaging analysis showing a small-to-moderate core infarct. For the first 71 patients enrolled, the infarct core size was defined based on CT perfusion imaging analyzed with an operator-independent postprocessing software; for the remainder of the study, infarct core size could be determined by CT perfusion imaging or non-contrast CT with a small-to-moderate core infarct based on ASPECTS. Patients were randomized to mechanical embolectomy with the Solitaire 2 or the Solitaire FR® device (n=98) or to ongoing IV tPA (n=98). Enrollment was planned for a maximum of 833 subjects but stopped at 196 subjects after an interim analysis, following the publication of the results of the MR CLEAN (see below) and ESCAPE trials, showed that results met SWIFT PRIME's prespecified efficacy criteria.

In the intervention group, a stent retriever was successfully deployed in 87 (89%) patients. At 90 days, 60% of endovascular therapy group patients were functionally independent (modified Rankin Scale score, 0-2) compared with 35% of control subjects (absolute risk reduction, 25%; OR=1.70; 95% CI, 1.23 to 2.33; p<0.001). Endovascular therapy group patients compared with controls were more likely to have successful (≥90%) reperfusion at 27 hours (83% vs 40%, respectively; OR=2.05; 95% CI, 1.45 to 2.91; p<0.001). Rates of death and serious adverse events did not differ significantly between groups.

MR CLEAN Trial. Berkhemer et al (2015) reported on initial results of the MR CLEAN trial an open-label, blinded endpoint RCT with 500 subjects conducted at 16 centers in the Netherlands. Eligible patients had an acute ischemic stroke caused by an intracranial occlusion of the distal intracranial carotid artery, middle cerebral artery (M1 or M2), or anterior cerebral artery (A1 or A2), and a score of 2 or higher on the National Institutes of Health Stroke Scale. Initiation of intra-arterial treatment had to be possible within six hours of stroke onset. Patients were randomized to standard stroke treatment (n=267 [53.4%]) or intra-arterial treatment (n=233 [46.6%]). Most patients in both groups (87.1% in the intervention group, 90.6% in the control group) received IV alteplase, at a median of 85 and 87 minutes after stroke onset, respectively. Patients in the intra-arterial group underwent arterial catheterization with a microcatheter to the level of the occlusion. Specific treatment options included delivery of a thrombolytic agent, mechanical thrombectomy, or both, at the discretion of the local interventionist. Intra-arterial thrombolytic agents were either alteplase or urokinase; mechanical treatment could involve thrombus retraction, aspiration, wire disruption, or use of a retrievable stent. The analysis was intention-to-treat. One control group patient received intra-arterial treatment, and 17 (7.3%) patients in the intervention group did not receive intra-arterial therapy, most commonly (n=8) due to clinical improvement before the start of the intervention. Among the 233 patients randomized to intra-arterial therapy, 195 (83.7%) received mechanical therapies, with retrievable stents used in 190 (81.5%) patients and other devices in 5 (2.1%) patients. Twenty-four (10.3%) patients received additional intra-arterial thrombolytic agents. The intra-arterial intervention was not performed after catheterization in 20 subjects for the following reasons: intracranial artery stenosis, occlusion, tortuosity, or dissection (n=10); lack of clot or targetable clot visible for intra-arterial therapy (n=8); or other technical problems (n=2).

For the study’s primary outcome (modified Rankin Scale score at 90 days), the median score was 3 (interquartile range, 2-5) among intervention subjects, compared with a median score of 4 (interquartile range, 3-5) among control subjects, with an unadjusted common OR of 1.66 (95% CI, 1.21 to 2.28; favoring intervention). Twenty-seven (11.6%) intervention subjects had a modified Rankine score of 0 or 1 at 90 days, compared with 16 (6.0%) control subjects (unadjusted OR=2.06; 95% CI, 1.08 to 3.92). Follow-up computed tomography angiography was available for
187 control subjects, of whom 141 (75.4%) had no intracranial occlusion, compared with 68 (32.9%) of 207 control subjects with follow-up computed tomography angiography available (unadjusted OR=6.27; 95% CI, 4.03 to 9.74). The 30-day mortality rate was 18.9% in the intervention group and 18.4% in the control group (p=NS). Rates of serious adverse events during the 90-day follow-up did not differ significantly between groups (p=0.31). Symptomatic intracerebral hemorrhage occurred in 7.7% of intervention subjects and 6.4% of control subjects, which did not differ significantly. However, intervention subjects were more likely to demonstrate a new ischemic stroke in different vascular territory (5.6% vs 0.4% p<0.001).

MR RESCUE Trial. Kidwell et al (2013) reported on the MR RESCUE trial.19, MR RESCUE was an open-label, blinded-outcome RCT of 118 patients from 22 North American sites. All patients had large vessel, anterior circulation ischemic strokes and were stratified by penumbral pattern, as determined by pretreatment CT or magnetic resonance imaging of the brain. Patients were randomized to standard stroke treatment (n=54) or mechanical embolectomy (n=64) using the Merci® Retriever or Penumbra System® within 8 hours after presentation of symptoms. Eight patients in the embolectomy group also had tPA. The primary hypothesis of the trial was that patients with favorable penumbral patterns (at-risk area of viable ischemic cerebral tissue of £70% and a small, £90 mL, area of predicted core infarct) would benefit more from mechanical embolectomy than patients with non-penumbral patterns (large infarct area and small or absent penumbra (viable ischemic cerebral tissue)), as determined by the 90-day modified Rankin Scale score. In the embolectomy group, 67% achieved revascularization, but this was not superior to standard care. Mean modified Rankin Scale scores were the same (3.9) in both groups, and pretreatment imaging patterns did not show any relation to treatment outcomes in any group. Overall mortality (21% at 90 days) and symptomatic intracranial hemorrhage (4%) did not differ across groups.

SYNTHESIS EXP (Intra-arterial Versus Systemic Thrombolysis for Acute Ischemic Stroke) Trial. Ciccone et al (2013) reported on the SYNTHESIS Expansion trial, which evaluated 362 patients randomized within 4.5 hours of the onset of various types of acute ischemic strokes to endovascular therapy (n=181) or IV tPA (n=181).18 Endovascular therapy consisted of intra-arterial tPA, mechanical embolectomy (using the Solitaire®, Penumbra®, Trevo® Merci® devices), or a combination of these treatments. Among patients randomized to endovascular therapy, endovascular treatment was completed in 163 patients. In 109 patients, regional intra-arterial infusion of tPA and fragmentation of the thrombus with a micro guidewire were used. In 56 patients, a device was added; the most widely used devices were Solitaire FR® in 18 patients, Penumbra in 9 patients, Trevo® in 5 patients, and Merci® in 5 patients. No significant differences in 90-day survival without disability (modified Rankin Scale score range, 0-1) occurred between the endovascular therapy (30.4%) group and tPA group (34.8%; adjusted OR=0.71; 95% CI, 0.44 to 1.14; p=0.16). Within seven days, fatal or nonfatal symptomatic intracranial hemorrhage occurred in each group at a rate of 6%. Rates of other serious adverse events also did not differ significantly between groups. While there were different treatment approaches in the endovascular group, these results would suggest endovascular therapy is not superior to tPA.

IMS III (Interventional Management of Stroke III) Trial. Broderick et al (2013) reported on the results of the IMS III trial, an open-label RCT with a planned enrollment of 900 patients.20 This trial enrolled patients with acute ischemic stroke who presented within 3 hours of symptom onset and had a moderate-to-severe neurologic deficit on presentation. Patients were randomized to IV tPA alone or IV tPA plus endovascular intervention. Patients randomized to the endovascular group underwent immediate angiography followed by endovascular intervention if a treatable vascular occlusion was present. The endovascular intervention consisted of either endovascular delivery of tPA at the site of occlusion or mechanical thrombectomy, at the discretion of the treating physician. Potential endovascular interventions included thrombectomy (using the Merci® Retriever, Penumbra System®, or Solitaire FR® revascularization device) or endovascular delivery of tPA (using the Micro-Sonic SV infusion system [EKOS] or a standard microcatheter). The primary outcome was a modified Rankin Scale score of 2 or less at 90 days. The trial was stopped prematurely due to futility after enrollment of 656 patients. At that point, the primary
outcome had been reached by 40.8% of patients in the endovascular group and 38.7% of patients in the IV tPA group. The adjusted difference in the primary outcome was 1.5% with a 95% CI for the difference of -6.1 to 9.1. Subarachnoid hemorrhage was more frequent in the endovascular group than in the tPA group (11.5% vs 5.8%, respectively; \( p = 0.02 \)), as was asymptomatic intracerebral hemorrhage (27.4% vs 18.9%, \( p = 0.01 \)). There were no significant differences between groups in other adverse events, including death and symptomatic intracerebral hemorrhage. In a predefined subgroup analysis, the trials reported that for the subgroup of patients with internal carotid artery, M1, or basilar artery occlusion who received tPA within 120 minutes of stroke onset (\( n = 124 \)), the RR for a modified Rankin Scale score of 2 or less at 90 days was not statistically significant (RR = 1.18; 95% CI, 0.66 to 2.1).

Tomsick et al (2015) published a subgroup analysis of the IMS III trial focusing on subjects with intracranial internal carotid artery or M1 occlusion.34 This analysis included 200 subjects, 65 with intracranial internal carotid artery and 135 with M1 segments as the target vessel for revascularization. Of these, at angiography, 82% had an arterial occlusive lesion score of 2 to 3 and 76% had a modified thrombolysis in cerebral infarction scores of 2 or 3 (partial or full perfusion) after IV tPA, which may have limited the potential benefit for device-related revascularization. Ninety-day modified Rankin Scale scores were higher with higher modified thrombolysis in cerebral infarction scores of 0 or 2.31 had a modified Rankin Scale score of 0 to 2 at 90 days, compared with 12.5%, 19.4%, 46.3%, and 80% for subjects with modified thrombolysis in cerebral infarction scores of 1 (\( n = 16 \)), 2a (\( n = 67 \)), 2b (\( n = 80 \)), and 3 (\( n = 5 \)), respectively. To account for potential bias in the choice of endovascular therapy, propensity score analysis was used to compare subjects with different endovascular therapy modalities for the primary study outcomes. After propensity score adjustment, trialists found no clear differences in clinical or revascularization outcomes across revascularization methods, which included standard microcatheter thrombolysis (\( n = 51 \)), the EKOS catheter (\( n = 14 \)), the Merc device (\( n = 77 \)), the Penumbra device (\( n = 39 \)), the Solitaire device (\( n = 4 \)), and other methods (\( n = 15 \)).

In another IMS III subgroup analysis, Demchuk et al (2014) evaluated the association between baseline CT or magnetic resonance angiography findings and outcomes among 306 (47%) of 656 who had baseline CT or magnetic resonance angiography available.35 Ninety-two percent of those with angiography available had arterial occlusions demonstrated, 220 of which were proximal occlusions. Endovascular therapy group subjects with proximal occlusions had higher 24-hour recanalization rates than those with IV tPA-only (84.3% of endovascular therapy subjects vs 56% of controls; \( p < 0.001 \)). However, no difference in the primary outcome (90-day modified Rankin Scale score of 0-2) was seen with proximal occlusions between groups (41.3% of endovascular therapy subjects vs 38% of controls; RR = 1.07; 99% CI, 0.67 to 1.70).

**Treatment Beyond Six Hours of Symptom Onset**

While the other trials assessing endovascular treatment focused on patients who were treated within the first several hours (generally within 6 to 8 hours) after the onset of stroke symptoms, the DEFUSE 3 (Endovascular Therapy Following Imaging Evaluation for Ischemic Stroke 3) and DAWN (Clinical Mismatch in the Triage of Wake Up and Late Presenting Strokes Undergoing Neuro-intervention With Trevo®) trials evaluated whether it was possible to extend the time window for mechanical thrombectomy after a acute ischemic stroke.

DEFUSE 3 Trial. Albers et al (2018) reported on results of DEFUSE 3, a multicenter, open-label RCT with blinded outcome assessment including patients 6 to 16 hours after they were last known to be well and who had remaining ischemic brain tissue that was not yet infarcted.6 DEFUSE 3 was conducted at 38 sites in the U.S. from May 2016 to May 2017. Patients were assigned to thrombectomy plus standard medical therapy (\( n = 92 \)) or standard medical therapy alone (\( n = 90 \)). The median age was 70 years, half of the participants were women, the median National Institutes of Health Stroke Scale score was 16, and 10% of the participants received IV tPA. Approximately 50% of the patients had a “wake-up” stroke. The trial was originally designed to enroll a maximum of 476 participants but was stopped early for efficacy. The proportion of
patients who were functionally independent (modified Rankin Scale score ≤2) at 90 days was 45% in the thrombectomy group and 17% in the standard care group (OR=2.67; 95% CI, 1.60 to 4.48; p < 0.001). The proportion of patients with symptomatic intracranial hemorrhage was 7% in the thrombectomy group and 4% in the standard care group (OR=1.47; 95% CI, 0.40 to 4.55; p = 0.75). The 90-day mortality rate was 14% in the thrombectomy group and 26% in the standard care group (OR=0.55; 95% CI, 0.30 to 1.02; p = 0.05). The rate of serious adverse events was 43% and 53%, respectively (p = 0.18).

DAWN Trial. Nogueira et al (2018) reported on results of the DAWN trial, a multicenter, Bayesian, adaptive, open-label RCT with blinded outcome assessment sponsored by Stryker Neurovascular. DAWN included patients who had last been known to be well 6 to 24 hours earlier and who had a mismatch between the severity of the clinical deficit and the infarct volume. DAWN was conducted at 26 sites in the U.S., Canada, Europe, and Australia from September 2014 through February 2017. Patients were assigned to thrombectomy plus standard care (n=107) or standard care alone (n=99). Very few patients were treated with IV tPA because patients were generally enrolled after the accepted window of time in which IV tPA is administered. The adaptive trial was originally designed for a sample size ranging from 150 to 500 patients but was stopped early due to efficacy. The mean age was 70 years, and the median National Institutes of Health Stroke Scale score was 17. Approximately 55% of the patients had a “wake-up” stroke. The proportion of patients with functional independence (modified Rankin Scale score ≤2) at 90 days was 49% in the thrombectomy group and 13% in the standard care group (adjusted difference, 33%; 95% credible interval, 24% to 44%; posterior probability of superiority, >0.999). The proportion of patients with symptomatic intracranial hemorrhage at 24 hours was 6% in the thrombectomy group and 3% in the standard care group (p = 0.50). The 90-day mortality rate was similar between groups (19% vs 18%, respectively; p = 1.00).

Section Summary: RCTs Comparing Endovascular Therapies with Noninterventional Care
A number of RCTs have compared endovascular therapies with noninterventional care for acute stroke, with the 5 more recent (2014-2015) studies demonstrating a significant benefit associated with endovascular care. The more recently published trials addressed some of the limitations of previous studies. In the IMS III and SYNTHESIS Expansion trials, sizable proportions of the endovascular therapy groups did not receive an endovascular device. All 3 of the 2013 trials (Ciccone et al [2013], Kidwell et al [2013], Broderick et al [2013]) had relatively low utilization of the newer generation retrievable stents (Solitaire FR®, Trevo®). Also, IMS III and SYNTHESIS Expansion did not require a radiologically proven intracranial occlusion for study eligibility. In contrast, the 2014-2015 trials, which demonstrated a benefit to endovascular therapy, either exclusively used stent retriever devices or allowed the treating physician to select a device, mostly a stent retriever device, and had high rates of mechanical embolectomy device use in patients randomized to endovascular therapy.

RCTs Comparing Different Endovascular Therapies
In 2012, 2 noninferiority RCTs comparing newer devices with the Merci® Retriever were completed as part of the FDA application for approval of the Solitaire and the Trevo® devices. Both studies reported device superiority over the Merci® device. In the SWIFT study, re-occlusion rates with Solitaire were compared with the Merci® Retrieval System in a randomized, prospective noninferiority trial of 113 patients with moderate or severe large vessel occlusion strokes. Treatment was initiated within eight hours of symptom onset in patients who had unsuccessful IV tPA or were ineligible for IV tPA. This trial was halted early after an interim analysis found revascularization without symptomatic intracranial hemorrhage occurred in 61% of Solitaire patients compared with 24% of Merci® patients. Mortality rates at 90 days were 17% with Solitaire vs 38% with Merci® (p = 0.001). A follow-up analysis of complications of endovascular procedures using the SWIFT study data was published in 2014. This analysis included 144 patients with acute ischemic stroke (31 patients treated with the Solitaire FR® device during the SWIFT trial roll-in period, 113 patients randomized to the Solitaire FR® or Merci® device). Major periprocedural complications, including symptomatic intracranial hemorrhage, air emboli, vessel dissection, major groin complications, and emboli to new vascular territories, were seen in 18
(12.5%) of 144 of patients. Complication rates were similar for patients receiving the Solitaire FR®
and Merci® devices, except symptomatic cerebral hemorrhage, which was significantly less
common in the Solitaire FR® group (10.9% vs 1.1%, p=0.013).

In the TREVO 2 (Thrombectomy Revascularization of large Vessel Occlusions) Study, 178 patients
were randomized to mechanical embolectomy with either the Trevo® Retriever or the Merci®
Retriever for large vessel occlusion strokes.38 Revascularization rates were 86% in the Trevo®
group and 60% in the Merci® group (p<0.001). Procedure-related adverse events occurred in
15% of the Trevo® group and 23% in the Merci® group (p=0.183). Mortality rates at 90 days were
33% and 24% (p=0.18), respectively.

Saposnik et al (2015)39 evaluated the benefit added by stent retrievers to IV tPA using pooled
patient-level data from the SWIFT study36 and the STAR trial, a prospective, single-arm trial of the
Solitaire device, along with data from the National Institute for Neurological Disorders tPA
Stroke Study, an RCT evaluating IV tPA. Of 915 patients included in the pooled analysis, 312 were
treated with placebo, 312 with IV tPA, 106 with stent retrievers alone, and 160 with IV tPA and
stent retrievers. The authors employed a shift analysis, which uses a proportional odds model, to
evaluate the association between treatment and each of the 7 modified Rankin Scale
categories. The use of stent retrievers (alone or with tPA) was associated with a higher
probability of functional independence (modified Rankin Scale score, 0-2) at 90 days: 41% of
those treated with tPA alone, 69.8% of those treated with stent retrievers, and 72.8% of those
treated with stent retrievers and tPA had functional independence at 90 days.

Noguiera et al (2018) compared use of the Penumbra 3-D stent retriever and an aspiration-
based mechanical thrombectomy device with the Penumbra aspiration system alone in 198
patients from 25 North American sites enrolled from May 2012 through November 2015.41 Eligible
patients had large vessel intracranial occlusion acute ischemic stroke with an National Institutes
of Health Stroke Scale score of at least eight within eight hours of onset. The primary
effectiveness outcome was the rate of a modified thrombolyis in cerebral infarction score of 2
to 3, with a 15% noninferiority margin. One hundred ninety patients were included in the primary
analysis. Eighty-two (87%) of 94 patients in the 3-D stent retriever group had a modified
thrombolyis in cerebral infarction score of 2 to 3 compared with 79 (82%) of 96 in the aspiration
alone group (difference, 4.9%; 90% CI, -3.6% to 13.5%). The incidence of the device- and
procedure-related serious adverse events within 24 hours of the procedure was 4 (4%) of 98
patients in the 3-D stent retriever group and 5 (5%) of 100 in the aspiration alone group.

Section Summary: Endovascular Interventions for Anterior Circulation Acute Ischemic Strokes
From 2013 to 2015, 8 published RCTs compared endovascular therapies with noninterventional
care for patients with a acute stroke due to anterior circulation occlusions. Several additional trials
were stopped early after the trials published in 2013 through 2015. Five trials published from 2014
to 2015 all demonstrated a significant benefit regarding reduced disability at 90 days post-
treatment. The trials were generally rated as having low-risk of bias in systematic reviews. The
trials that demonstrated a benefit for endovascular therapy either exclusively used stent retriever
devices or permitted treating physicians to select a device, mostly a stent retriever device, and
had high rates of mechanical embolectomy device use in patients randomized to endovascular
therapy. All studies that demonstrated a benefit for endovascular therapy required
demonstration of a large vessel and anterior circulation occlusion for enrollment. Also, they were
characterized by fast time-to-treatment. Two trials published in 2018 demonstrated that it was
possible to extend the time window for mechanical thrombectomy up to about 24 hours for
select patients. To achieve results in real-world settings similar to those in the clinical trials,
treatment times, clinical protocols, and patient selection criteria should be similar to those in the
RCTs.

Endovascular Interventions For Stroke Due To Basilar Artery Occlusion
Posterior circulation strokes account for about 20% of all acute ischemic strokes; occlusion of the
basilar artery is implicated in about 8% of posterior strokes.42 Reperfusion therapies have
received particular attention as a therapy for basilar artery occlusion because, though relatively rare, those occlusions have a high likelihood of severe disability or death. For example, in a registry study, Schonewille et al (2009) found severe outcomes (modified Rankin Scale scores of 4 or 5, or death) in 68% of patients with basilar artery occlusion.43

**Review of Evidence**

**Randomized Controlled Trials**

Liu et al (2020) reported results of the Basilar Artery Occlusion Endovascular Intervention versus Standard Medical Treatment (BEST) multicenter, open-label, RCT with blinded outcome assessment conducted at 28 stroke centers in China comparing endovascular plus standard medical therapy (n=66) to standard medical therapy (n=65) for treatment of acute strokes due to vertebrobasilar artery occlusion. Patients had an acute ischaemic stroke consistent with acute occlusion of the basilar artery presenting within 8 hours of vertebrobasilar occlusion and a prestroke score of 0-2 on the modified Rankin Scale. The primary outcome was a modified Rankin Scale score of 3 or lower (indicating ability to walk unassisted) at 90 days. Patients in both groups meeting criteria for intravenous thrombolysis received intravenous alteplase and received standard medical therapy following the American Heart Association/American Stroke Association guidelines. The trial was designed with a sample size of 344 patients but was terminated prematurely by the steering committee based on the recommendation of the data and safety monitoring board because of excessive crossovers and poor recruitment. Characteristics of the study are shown in Table 3 and results are shown in Table 4. In the intention-to-treat analysis, there was not a statistically significant difference in the proportion of participants with modified Rankin Scale 0-3 at 90 days (28 / 66 [42%] in the endovascular group vs 21 / 65 [32%] in the standard therapy group; adjusted odds ratio = 1.7, 95% CI, 0.8 to 3.7). The 90-day mortality rates were 33% vs 38% in the endovascular and standard therapy groups respectively (p=0.54).

**Table 3. Summary of RCT Characteristics of Endovascular Treatment of Basilar Artery Occlusion**

<table>
<thead>
<tr>
<th>Trial</th>
<th>Countries</th>
<th>Sites</th>
<th>Dates</th>
<th>Participants</th>
<th>Interventions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Liu 2020</td>
<td>China</td>
<td>28</td>
<td>2015 to 2017</td>
<td>Patients ages 18 years or older; had an acute ischaemic stroke consistent with acute occlusion of the basilar artery; could be randomized within 8 hours of symptom onset; had a prestroke score of 0-2 on the mRS</td>
<td></td>
</tr>
<tr>
<td><strong>BEST; NCT02441556</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>N=66 Endovascular therapy plus standard medical therapy</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>N=65 Standard medical therapy</td>
</tr>
</tbody>
</table>

**Table 4. Results of RCTs of Endovascular Therapy of Basilar Artery Occlusion**

<table>
<thead>
<tr>
<th>Trial (Study)</th>
<th>N</th>
<th>90-Day Modified Rankin Scale Score 0-3</th>
<th>Mortality</th>
<th>Symptomatic Intracranial Hemorrhage</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Per Group Rate, %</td>
<td>Between-Group Difference (95% CI)</td>
<td>Per Group Rate, %</td>
</tr>
<tr>
<td>Liu 2020[^44]</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Endovascular therapy plus standard medical therapy</td>
<td>42%</td>
<td>OR=1.7 (0.8 to 3.7)</td>
<td>33%</td>
<td>0.8 (0.4 to 1.6)</td>
</tr>
<tr>
<td>Standard medical therapy</td>
<td>32%</td>
<td></td>
<td>38%</td>
<td></td>
</tr>
</tbody>
</table>

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The purpose of the gap tables (see Tables 5 and 6) is to display notable gaps identified in each study. This information is synthesized as a summary of the body of evidence following each table and provides the conclusions on the sufficiency of evidence supporting the position statement.

Table 5. Relevance Gaps of RCTs of Endovascular Treatment of Basilar Artery Occlusion

<table>
<thead>
<tr>
<th>Study</th>
<th>Populationa</th>
<th>Interventionb</th>
<th>Comparatorc</th>
<th>Outcomesd</th>
<th>Follow-Up e</th>
</tr>
</thead>
<tbody>
<tr>
<td>Liu 2020 [4]</td>
<td>44; 14 (22%) of 65 patients received endovascular treatment because patients' families did not accept only standard medical therapy after randomization</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

RCT: randomized controlled trial.

The evidence gaps stated in this table are those notable in the current review; this is not a comprehensive gaps assessment.

a Population key: 1. Intended use population unclear; 2. Clinical context is unclear; 3. Study population is unclear; 4. Study population not representative of intended use.

b Intervention key: 1. Not clearly defined; 2. Version used unclear; 3. Delivery not similar intensity as comparator; 4. Not the intervention of interest.

c Comparator key: 1. Not clearly defined; 2. Not standard or optimal; 3. Delivery not similar intensity as intervention; 4. Not delivered effectively.

d Outcomes key: 1. Key health outcomes not addressed; 2. Physiologic measures, not validated surrogates; 3. No CONSORT reporting of harms; 4. Not establish and validated measurements; 5. Clinical significant difference not prespecified; 6. Clinical significant difference not supported.

e Follow-Up key: 1. Not sufficient duration for benefit; 2. Not sufficient duration for harms.

Table 6. Study Design and Conduct Gaps of RCTs of Endovascular Treatment of Basilar Artery Occlusion

<table>
<thead>
<tr>
<th>Study</th>
<th>Allocationa</th>
<th>Blindingb</th>
<th>Selective Reportingc</th>
<th>Data Completenessd</th>
<th>Power e</th>
<th>Statistical f</th>
</tr>
</thead>
<tbody>
<tr>
<td>Liu 2020 [4]</td>
<td>1,3: Study terminated early due to high crossovers and poor recruitment</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

RCT: randomized controlled trial.

The evidence gaps stated in this table are those notable in the current review; this is not a comprehensive gaps assessment.


d Data Completeness key: 1. High loss to follow-up or missing data; 2. Inadequate handling of missing data; 3. High number of crossovers; 4. Inadequate handling of crossovers; 5. Inappropriate exclusions; 6. Not intent to treat analysis (per protocol for noninferiority trials).

e Power key: 1. Power calculations not reported; 2. Power not calculated for primary outcome; 3. Power not based on clinically important difference.

f Statistical key: 1. Analysis is not appropriate for outcome type: (a) continuous; (b) binary; (c) time to event; 2. Analysis is not appropriate for multiple observations per patient; 3. Confidence intervals and/or p values not reported; 4. Comparative treatment effects not calculated.

Section Summary: Endovascular Interventions for Stroke due to Basilar Artery Occlusion

The evidence for the use of endovascular interventions for stroke due to basilar artery occlusions is limited. One RCT has been conducted but it was terminated early due to high crossovers and poor recruitment. There was not a statistically significant difference in the proportion of participants with modified Rankin Scale 0–3 at 90 days or in 90-day mortality rates in the endovascular and standard therapy groups. At least 2 additional RCTs are ongoing.
Endovascular Interventions for Symptomatic Intracranial Atherosclerotic Disease

Clinical Context and Therapy Purpose

The purpose of endovascular interventions in patients with intracranial atherosclerotic disease is to prevent stroke or recurrent stroke.

The question addressed in this evidence review is: Do endovascular therapies improve the net health outcome in patients with intracranial atherosclerotic disease?

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

Patients
Patients with severe stenosis (70 to 99% of the diameter of a major intracranial artery).

Interventions
Devices for treatment of intracranial stenosis have received the FDA approval through the humanitarian device exemption process. The Neurolink System® was approved based on the Stenting of Symptomatic Atherosclerosis Lesions in the Vertebral or Intracranial Arteries (SSYLVIA) trial, a prospective, nonrandomized, multicenter, international study of 61 patients. The Wingspan™ Stent System was evaluated in a prospective study of 45 patients enrolled at 12 international centers. The SSYLVIA study reported an all-stroke rate of 13.1% over a mean follow-up of 216 days; the Wingspan™ study reported an all-stroke rate of 9.5% over a mean follow-up of 174 days.

The FDA summary of safety and effectiveness for the Wingspan™ device offered the following conclusions and the FDA appears to have based its approval of Wingspan™ in part on the favorable comparison with the Neurolink device:

“...the probable benefit to health from using the Wingspan™ Stent System with Gateway PTA [percutaneous transluminal angioplasty] Balloon Catheter for treating transcranial stenosis outweighs the risk of illness or injury when used in accordance with the Instructions for Use and when taking into account the probable risks and benefits of currently available alternative forms of treatment.”

Comparators
Medical treatment typically includes either anticoagulant therapy (i.e., warfarin) or antiplatelet therapy (e.g., aspirin). The Warfarin-Aspirin Symptomatic Intracranial Disease trial assessed the incidence of stroke brain hemorrhage or death among patients randomized to aspirin or warfarin. The trial found that over a mean 1.8 years of follow-up, warfarin provided no benefit over aspirin and was associated with a significantly higher rate of complications. Also, if symptoms could be attributed to low-flow ischemia, agents to increase mean arterial blood pressure and avoid orthostatic hypotension may be recommended. However, medical therapy has been considered less than optimal. For example, in patients with persistent symptoms despite antithrombotic therapy, the subsequent rate of stroke or death has been extremely high, estimated in 1 study at 45% with recurrent events within 1 month of the initial event. Surgical approaches have met with limited success. The widely cited extracranial-intracranial bypass study randomized 1377 patients with symptomatic atherosclerosis of the internal carotid or middle cerebral arteries to medical care or extracranial-intracranial bypass. Outcomes in both groups were similar, suggesting that the extracranial-intracranial bypass is ineffective in preventing cerebral ischemia. Due to inaccessibility, surgical options for the posterior circulation are even more limited.

Percutaneous transluminal angioplasty has been approached cautiously for use in intracranial circulation, due to technical difficulties in the catheter and stent design and the risk of embolism, which may result in devastating complications if occurring in the posterior fossa or brain stem. However, improvement in the ability to track catheterization, allowing catheterization of tortuous vessels, and the increased use of stents have created ongoing interest in percutaneous transluminal angioplasty as a minimally invasive treatment of this difficult-to-treat population.
Most published studies of intracranial percutaneous transluminal angioplasty have focused on vertebrobasilar circulation.

**Outcomes**
The outcomes of interest are stroke, death, function and quality of life. Treatment-related adverse effects, including vessel perforation, hemorrhage, or thrombus formation in a new site, are important safety outcomes. Evidence for both short-term (30 day) and long-term (out to 2-years) outcomes are needed.

**Study Selection Criteria**
1. Comparative controlled prospective trials, with a preference for RCTs were sought.
2. In the absence of such trials, comparative observational studies, with a preference for prospective studies may be included.
3. Single arm studies that captured longer periods of follow-up and/or larger populations may be included to assess long-term outcomes and adverse effects
4. Studies with duplicative or overlapping populations were excluded.

**Review of Evidence**

**Randomized Controlled Trials**
Zaidat et al (2015) published the results of the Vitesse Intracranial Stent Study for Ischemic Stroke Therapy (VISSIT) trial, an RCT comparing a balloon-expandable stent plus medical management with medical management alone among patients who had symptomatic intracranial stenosis of 70% or greater. Eligible patients had stenosis of 70% to 99% of the internal carotid, middle cerebral, intracranial vertebral, or basilar arteries with a transient ischemic attack (TIA) or stroke attributable to the territory of the target lesion within the prior 30 days. Enrollment was planned for up to 250 participants. However, an early unplanned analysis was conducted by the trial sponsor after the results of the Stenting and Aggressive Medical Management for Preventing Recurrent Stroke in Intracranial Stenosis (SAMMPRIS) trial were published (see below). A total of 112 patients were enrolled from 2009 to 2012 and randomized to the balloon-expandable stent (Vitesse stent) plus medical management (stent group; n=59) or medical management alone (medical group; n=53). Medical management included clopidogrel (75 mg daily) for the first 3 months post enrollment and aspirin (81-325 mg/d) for the duration of the study, along with management of hypercholesterolemia and/or hypertension, if necessary. The trial used a primary composite endpoint that included any stroke in the same territory as the presenting event within one year of randomization and “hard transient ischemic attack (TIA)” in the same territory as the presenting event from two days to one year after randomization. Among 29 patients who met one of the primary endpoints within 1 year of randomization, 8 (15.1%) patients were in the medical group, and 21 (36.2%) were in the stent group (risk difference, 21.1%; 95% CI, 5.4% to 36.8% p=0.02). The rates of stroke within 30 days of randomization or transient ischemic attack (TIA) were 9.4% in the medical group and 24.1% in the stent group (risk difference, 14.7%; 95% CI, 1.2% to 28.2% p=0.05). The 30-day all-cause mortality rate was 5.2% and 0% in the stent and the medical groups, respectively (risk difference, 5.2% 95% CI, -0.5% to 10.9% p=0.25). The authors concluded that results did not support the use of a balloon-expandable stent for patients with symptomatic intracranial stenosis.

The SAMMPRIS trial was an RCT comparing aggressive medical management alone with aggressive medical management plus stenting in patients who had symptomatic cerebrovascular disease and intracranial stenosis between 70% and 99%. This trial used the Wingspan™ stent system implanted by experienced neurointerventionalists credentialed to participate in the trial. The authors planned to enroll 750 patients based on power calculations. However, the trial was stopped early for futility after 451 patients had been randomized, due to an excess of the primary outcome (stroke or death) at 30 days in the stenting group. In the stenting group, the rate of stroke or death at 30 days was 14.7% (95% CI, 10.7% to 20.1%) compared with 5.8% (95% CI, 3.4% to 9.7% p=0.002) in the medical management group. At the time of trial termination, mean follow-up was 11.9 months. Kaplan-Meier estimates of the primary outcome (stroke or death at 1 year) was 20.5% (95% CI, 15.2% to 26.0%) in the stenting group and 12.2% (95% CI, 14.7% to 24.1% p=0.02).
8.4% to 17.6% (p = 0.009) in the medical management group. These results represented an excess rate of early adverse events with stenting over what was expected together with a decreased rate of stroke and death in the medical management group compared with expected values.

The SAMMPRIS investigators, as reported by Derdeyn et al (2014), also published results from long-term subject follow-up. Primary endpoints (in addition to stroke or death within 30 days of enrollment) included ischemic stroke in the qualifying artery beyond 30 days after enrollment or stroke or death within 30 days after a revascularization procedure of the qualifying lesion. During a median follow-up of 32.4 months, 34 (15%) of 227 of patients in the best medical management group and 52 (23%) of 224 patients in the stenting group had a primary endpoint event, with a significantly higher cumulative probability of a primary endpoint in the stenting group than in the best medical management group (p = 0.025). Compared with the best medical management group, subjects in the stenting group had higher rates of any stroke (59/224 [26%] vs 42/227 [19%], p = 0.047) and major hemorrhage (29/224 [13%] vs 10/227 [4%], p < 0.001). The authors concluded the benefits of aggressive medical management over percutaneous angioplasty and stenting among patients with intracranial stenosis persist over long-term follow-up.

Lutsep et al (2015) published a subgroup analysis of the SAMMPRIS trial results to evaluate whether outcomes differed for patients whose qualifying events occurred on or off anti-thrombotic therapy. Similar to the overall trial results, outcomes were worse in the stent group than in the best medical management group: of the 284 patients on antithrombotic therapy at the time of the qualifying event, 140 patients were randomized to medical management and 144 to stenting; in Kaplan-Meier analysis, 2 year rates of the primary end point were 15.6% in the medical management group and 21.6% in the stent group (p = 0.043). In other subgroup analyses of the SAMMPRIS trial results, 2 year event rates were higher in the stent group for most variables evaluated. The interaction between treatment and the subgroup variables was not significant for any variable.

The Carotid And Vertebral Artery Transluminal Angioplasty Study randomized 16 patients with symptomatic vertebral artery stenosis to endovascular therapy (balloon angioplasty or stenting) or best medical treatment alone. Endovascular intervention was technically successful in all 8 patients but 2 patients experienced TIA during endovascular treatment. During a mean follow-up of 4.7 years, no patient in either treatment group experienced a vertebrobasilar territory stroke, but three patients in each arm died of myocardial infarction or carotid territory stroke, and 1 patient in the endovascular arm had a nonfatal carotid territory stroke. The investigators concluded that patients with vertebral artery stenosis were more likely to have carotid territory stroke and myocardial infarction during follow-up than recurrent vertebrobasilar stroke. While they noted the trial failed to show a benefit of endovascular treatment of vertebral artery stenosis, the small number of patients enrolled severely limits conclusions.

Qureshi et al (2013) published results from another small RCT comparing angioplasty alone with angioplasty plus a balloon-expanding stent for 18 subjects who had moderate intracranial stenosis (≥50%) with documented failure of medical treatment or severe stenosis (≥70%) with or without failure of medical treatment. Technical success (<30% residual stenosis on immediate postprocedure angiography) occurred in 5 of 10 patients treated with angiography (9 randomized to angiography, 1 crossover from group randomized to stent placement) and 5 of 8 patients treated with stent placement. Rates of stroke or death were low in both groups (one of ten in the angiography group vs none in the stent placement group). This trial suggests that angioplasty with stenting is feasible in patients with severe intracranial stenosis, but the small sample size and lack of statistical comparisons limit conclusions that can be drawn.

**Postmarket Surveillance**

Alexander et al 2019 reported results from the WEAVE (Wingspan™ Stent System Post Market Surveillance) postmarketing surveillance study. WEAVE was an FDA mandated, prospective, single-arm study evaluating the rate of stroke and death within 72 hours poststenting in patients who met the FDA on-label usage criteria. One hundred fifty-two consecutive patients were
enrolled at 24 hospitals. The study was designed to enroll 389 patients but was stopped early when the second, predetermined interim data analysis indicated that the safety benchmarks were met. The primary outcome was stroke or death within 72 hours. The primary outcome included 2 nonfatal strokes and 2 deaths from strokes for a total of 4 patients (2.6%) with an event of stroke, bleed, or death.

Section Summary: Endovascular Interventions for Symptomatic Intracranial Atherosclerotic Disease

The strongest evidence on the efficacy of endovascular treatment for symptomatic intracranial stenosis is from the SAMMPRIS and VISSIT RCTs. The SAMMPRIS trial was stopped early due to harms because the rate of stroke or death at 30 days following treatment was higher in the endovascular arm, which received percutaneous angioplasty with stenting. Follow-up of the SAMMPRIS subjects has demonstrated no long-term benefit from endovascular therapy. The VISSIT RCT similarly found no benefit with endovascular treatment. These studies support the conclusion that outcomes of endovascular treatment are worse than medical therapy in patients with symptomatic intracranial stenosis.

Stent-Assisted Endovascular Treatment of Intracranial Aneurysms

Clinical Context and Therapy Purpose

The purpose of endovascular interventions in patients with intracranial aneurysm is to remove the aneurysm from the circulation and prevent possible rupture (or if the aneurysm had already ruptured, to stop bleeding and prevent re-rupture) or to divert blood flow away from an aneurysm.

The question addressed in this evidence review is: Do endovascular therapies improve the net health outcome in patients with intracranial aneurysm?

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

Patients

The population of interest are patients with intracranial aneurysms. Treatment decisions depend on patient and aneurysm characteristics. Small (<7 mm) asymptomatic aneurysms can generally be observed. Larger and asymptomatic aneurysms may be considered for treatment according to anatomical location and morphological characteristics of the aneurysm and relative risks for specific treatments. The FDA approved endovascular treatments have specific specifications regarding aneurysm characteristics (see Regulatory section) although they have been used off-label for challenging lesions in other locations.

Interventions

Self-expanding stents, have the FDA approval through the humanitarian device exemption program for the endovascular treatment intracranial aneurysms.

Intracranial stents are being used to treat cerebral aneurysms. Stent-assisted coiling began as an approach to treat fusiform or wide-neck aneurysms in which other surgical or endovascular treatment strategies may not be feasible. As experience has grown, stenting has also been used in smaller berry aneurysms as an approach to decrease the rate of retreatment needed in patients who receive coiling. A randomized trial has demonstrated that treatment of ruptured intracranial aneurysms with coiling leads to improved short-term outcome compared with surgical clipping; however, patients who receive coiling need more repeat or follow-up procedures.

In 2011, the Pipeline® Embolization Device, which falls into a new device category called “intracranial aneurysm flow diverters,” or flow-diverting stents, received the FDA premarket approval for endovascular treatment of large or giant wide-necked intracranial aneurysms in the internal carotid artery. The Pipeline® device is a braided, wire mesh device that is placed within the parent artery of an aneurysm to redirect blood flow away from the aneurysm, with the
goal of preventing aneurysm rupture and possibly decreasing aneurysm size. According to the FDA documentation, the Surpass Streamline Flow Diverter has the same mechanism of action as the approved Pipeline® Embolization Device.

**Comparators**
Small asymptomatic aneurysms can generally be observed without surgery. Surgical clipping of intracranial aneurysms has been used since the 1960s, but the feasibility of clipping for aneurysms depends on the aneurysm location.

**Outcomes**
The Executive Summary of an FDA meeting of the Neurological Devices Advisory Panel in 2018 to discuss evaluation of benefits and risks of new endovascular medical devices intended to treat intracranial aneurysms states the primary safety outcomes for regulatory review have traditionally been focused on neurological deaths and major ipsilateral strokes (defined as an increase ≥ 4 points in the National Institutes of Health Stroke Scale score during the stroke event) and the percentage of patients who had a disabling stroke (defined as modified Rankin Scale score ≥ 3 assessed at a minimum of 90 days post-stroke event) within 6 months to 1 year of treatment. The FDA is considering an additional outcome of to assess functional independence defined as the change in the modified Rankin Scale score at one year post-treatment compared to pre-procedure. The FDA has traditionally used a composite efficacy outcome defined as the percent of patients demonstrating a Raymond I classification for complete occlusion (i.e., 100% aneurysmal occlusion) without retreatment of the target aneurysm or significant parent artery stenosis (≥ 50%) evaluated within 1 year post-procedure.

**Study Selection Criteria**
1. Comparative controlled prospective trials, with a preference for RCTs were sought.
2. In the absence of such trials, comparative observational studies, with a preference for prospective studies may be included.
3. Single arm studies that captured longer periods of follow-up and/or larger populations may be included to assess long-term outcomes and adverse effects.
4. Studies with duplicative or overlapping populations were excluded.

**Self-Expanding Stent-Assisted Coiling for Intracranial Aneurysms**
The literature search did not identify any randomized trials of self-expanding stent-assisted treatment of intracranial aneurysms compared with standard neurosurgical treatment (i.e., surgical clipping or endovascular coils). The available evidence includes single-arm case series, registry studies, nonrandomized comparative studies, and a systematic review of nonrandomized comparative studies.

**Review of Evidence**

**Systematic Reviews**
Hong et al (2014) reported on the results of a systematic review and meta-analysis of studies that compared stent-assisted coiling with coiling alone for the treatment of intracranial aneurysms. Reviewers included 10 retrospective cohort studies, ranging in size from 9 to 1,109 patients. In pooled analysis, compared with coiling alone, stent-assisted coiling was associated with higher rates of progressive thrombosis (37.5% vs 19.4%; OR=2.75; 95% CI, 1.95 to 3.86; p<0.000) and lower rates of recurrence (16.2% vs 34.4%; OR=0.35; 95% CI, 0.25 to 0.49; p<0.000). The mortality rate was 9.1% for stent-assisted coiling compared with 2.6% for coiling alone, although the difference was not statistically significant (OR=2.31; 95% CI, 0.68 to 7.82; p=0.18). Similarly, permanent complication rates and thromboembolic complication rates did not differ significantly between the 2 groups.

Ryu et al (2015) conducted a systematic review of studies reporting complications after stent-assisted coiling of ruptured intracranial aneurysms, with a focus on complications related to antiplatelet therapy. They included 33 studies, 3 of which were prospective and the other 30 were retrospective (total n=1,090 patients). In pooled analysis, thromboembolic complications
occurred in 108 patients (event rate, 11.2%; 95% CI, 9.2% to 13.6%). Intraprocedural hemorrhage occurred in 46 (event rate, 5.4%; 95% CI, 4.1% to 7.1%).

Nonrandomized Comparative Studies

The largest comparative series describing the use of stents and coiling alone for treating intracranial aneurysms was described by Piotin et al (2010). They reported on a series of 1,137 patients (1,325 aneurysms) treated between 2002 and 2009. In this series, 1,109 (83.5%) aneurysms were treated without stents (coiling), and 216 (16.5%) were treated with stents (15 balloon-expandable and 201 self-expandable stents). Permanent neurologic procedure-related complications occurred in 7.4% (16/216) of those with stents vs 3.8% (42/1109) of those without stents (logistic regression p = 0.644; OR = 1.289; 95% CI, 0.439 to 3.779). Procedure-induced mortality occurred in 4.6% (10/216) of the procedures with stents vs 1.2% (13/1109) in those without (logistic regression p = 0.006; OR = 0.116; 95% CI, 0.025 to 0.531). At the time of publication, the authors had followed 53% (114/216) of aneurysms treated with stents and 70% (774/1109) of aneurysms treated without, with angiographic recurrence in 14.9% (17/114) vs 33.5% (259/774), respectively (p < 0.001; OR = 0.349; 95% CI, 0.204 to 0.596).

Additional smaller nonrandomized comparative studies, both prospective and retrospective, have evaluated stent-assisted coiling, compared with coiling alone, balloon-assisted coiling, or surgical clipping.

Hetts et al (2014) compared outcomes for patients treated using stent-assisted coiling with those treated using coiling alone for patients who had unruptured intracranial aneurysms who were enrolled in the prospective, nonrandomized, multicenter Matrix and Platinum Science Trial. The trial compared bare-metal aneurysm coils with polymer-coated aneurysm coils. One hundred thirty-seven patients received a stent-assisted coil, and 224 patients received coiling alone. Patients treated with stent-assisted coiling more often had wide-neck aneurysms (62% vs 33%; p < 0.000) and had aneurysms with the lower dome-to-neck ratio (1.3 vs 1.8; p < 0.000). Periprocedural serious adverse events occurred in 6.6% of those treated with stent-assisted coiling, compared with 4.5% of those treated with coiling alone (p = 0.039). At 1 year, ischemic strokes were more common in patients who received a stent-assisted coil than in patients who received a coil alone (8.8% vs 2.2%; p = 0.005). However, in multivariable analysis, stent use did not independently predict ischemic stroke at 2 years (adjusted OR = 1.1; p = 0.94).

Consoli et al (2016) compared stent-assisted coiling with balloon-assisted coiling in patients who had unruptured wide-necked intracranial aneurysms treated at a single-center. The study included 268 patients (286 aneurysms), 117 (122 aneurysms) of whom were treated with stent-assisted coiling and 151 (164 aneurysms) of whom were treated with balloon-assisted coiling. At discharge, 97.9% and 97.3% of those in the balloon-assisted and stent-assisted groups, respectively, had Rankin Scale scores of 0 or 1 (statistical comparison not reported). After 6 months, 97.9% and 98% of those in the balloon-assisted and stent-assisted groups, respectively, had Rankin Scale score of 0 or 1, while mortality rates were 2.6% and 1.7% in the balloon-assisted and stent-assisted groups, respectively (statistical comparisons not reported). At 6 months, aneurysm recurrence rates were 11.1% and 5.8% in the balloon-assisted and stent-assisted groups, respectively. In multivariable analysis, the use of stent-assisted coiling was significantly associated with complete occlusion at the end of the procedure (regression coefficient not reported; p = 0.024) and complete occlusion after 6 months (regression coefficient not reported; p = 0.05).

A nonrandomized comparative study by Hwang et al (2011) from Korea reported on 126 aneurysms treated with stent-assisted coiling and 86 treated with coil alone. At 2 year follow-up, the authors reported rates of occlusion and recurrence. Progressive occlusion was noted in 42.5% (17/40) of the stent group and 39.5% (34/86) of the nonstented group (p = NS). The rates of aneurysm recurrence also did not differ statistically between groups. The aneurysm recurrence rate was 17.5% of patients in the stent group and 21.0% in the nonstent group.
Liu et al (2014) retrospectively compared outcomes for patients who had posterior communicating artery aneurysms treated using stent-assisted coiling with those treated using coiling alone. A total of 291 coiling procedures were performed, including 56 aneurysms treated with a self-expandable stent. Complete aneurysm occlusion on initial angiography occurred in 41.1% of stent-assisted coiling patients compared with 35.3% of nonstented patients (statistical comparison not reported). At last follow-up (mean, 14.3 months for stent-assisted coiling and 13.2 months for nonstent patients), the aneurysm recurrence rates were 10.6% in stent-assisted coiling patients and 28.1% of nonstent patients ($p=0.014$). Procedural complications occurred in 10.7% of stent-assisted coiling patients compared with 11.5% of nonstent patients ($p=NS$).

Colby et al (2012) reported on 90 consecutive patients undergoing treatment for para-ophthalmic aneurysms, 30 of whom were treated with coil alone and 60 with stent-assisted coils. On initial angiography following the procedure, complete occlusion of the aneurysm was achieved in 43.3% of stented patients compared with 31.7% of nonstented patients. At a mean 14.5-month follow-up, the recurrence rate was lower in the stented group (15.4% [4/26]) than in the nonstented group (41.5% [17/41]; $p<0.05$).

**Comparison Between Endovascular Devices for Intracranial Aneurysms**

Nonrandomized studies, summarized in a systematic review by King et al (2015), have compared devices used for stent-assisted coiling of intracranial aneurysms. Reviewers evaluated published studies reporting on stent-assisted coiling with the Neuroform™ and Enterprise™ systems to assess outcomes between the devices. The analysis included 47 studies with a total of 4,039 patients (4,238 aneurysms; 2,111 treated with Neuroform™ and 2,127 with Enterprise™). Most (81%) studies were retrospective. Compared with those treated using the Enterprise™ system, patients treated using the Neuroform™ system were more likely to have deployment failure (2.3% vs 0.2%, $p<0.001$) and a higher mortality rate (2.8% vs 1.8%, $p=0.04$), less likely to have 100% aneurysm occlusion at last follow-up (61.1% vs 74.7%, $p<0.001$), and more likely to have recanalization (13.9% vs 10.6%, $p=0.02$). However, conclusions drawn from these findings are influenced by the potential for bias in the underlying studies and between-study heterogeneity.

**Single-Arm Series**

A large number of single-arm series have reported outcomes for stent-assisted coiling.

**Systematic Reviews**

A literature review by Shapiro et al (2012) identified 39 articles (total n=1517 patients), most of which were single-arm, retrospective series. Most patients treated had unruptured aneurysms, but 22% had ruptured aneurysms. Reviewers noted a large amount of heterogeneity in reporting outcomes data, particularly for adverse events. The perioperative mortality rate was 2.1%, and the overall complication rate was 19%. Immediately after treatment, approximately 45% of patients had occlusion of the aneurysm. At an average of 13 months posttreatment, the stroke rate in the stented area was 3.2%.

A systematic review focusing only on ruptured aneurysms was published by Bodily et al (2011). This review selected 17 articles that described treatment in 212 patients. Technical success was high (93%), and 2% of patients required open surgery due to stent failure or intraoperative aneurysm rupture. Sixty-three percent (130/207) of aneurysms were successfully occluded. The overall mortality rate was 19% and 14% of patients had poor clinical outcomes. A relatively high rate of adverse events was reported, with 8% of patients having an acute procedure-related intracranial bleeding and 6% (16/288) having a clinically significant thromboembolic event.

**Nonrandomized Comparative Studies**

Since the publication of the Shapiro et al (2012) and the Bodily et al (2011) reviews, a number of noncomparative studies evaluating the use of stent-assisted endovascular treatments in intracranial aneurysms have been published.
A large study, reported by Geyik et al (2013), included 468 patients with wide-necked cerebral aneurysms who underwent stent-assisted coiling with the Enterprise™, Neuroform™, Wingspan™, or (self-expanding) Leo (Balt Extrusion) stents.68 The overall mortality rate was 1.9%; procedure-related complications occurred in 28 (6.9%) patients. Angiographic follow-up data, obtained from 6 months to 7 years postprocedure (mean, 19.2 months), were available for 440 (94%) patients. For the total of 467 aneurysms with follow-up, complete occlusion occurred in 194 (41.6%) aneurysms, near-complete occlusion (>95% occlusion but minimal residual filling with coils at the neck) occurred in 242 (51.8%) aneurysms, and incomplete occlusion (<95%) occurred in 31 (6.6%) aneurysms. At 6-month follow-up, recanalization occurred in 38 aneurysms (8% of all aneurysms with follow-up available). The authors concluded that stents were associated with high rates of occlusion and low rates of recurrence over long-term follow-up.

In a larger study, Lee et al (2016) reported on 1,038 patients treated with endovascular coiling, 296 of whom underwent stent-assisted coiling, with a focus on predictors of procedural rupture.69 Three cases of procedural rupture occurred among patients treated with stent-assisted coiling.

Other representative noncomparative studies in which at least some patients were treated with devices commercially available in the U.S. are summarized in Table 7. Interpretation of these studies is limited by potential selection bias and lack of comparison groups. In general, these series demonstrate high rates of technical success of stent deployment with high rates of aneurysm occlusion; however, variable complication rates, particularly related to thromboembolic events, were observed.

Table 7. Noncomparative Studies of Stent-Assisted Endovascular Treatment of Aneurysms

<table>
<thead>
<tr>
<th>Study</th>
<th>Study Type</th>
<th>Population</th>
<th>Intervention</th>
<th>Primary Outcome</th>
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<tr>
<td>ATLAS IDE study: Jankowitz et al (2019) [26](30 patients enrolled through September 2015)FDA SSED [71](201 patients enrolled through October 2016)</td>
<td>Prospective, multicenter (25 sites)</td>
<td>201 patients with wide-necked intracranial aneurysm (neck ≥4 mm or dome-to-neck ratio &lt;2), parent vessel diameter of 2.0–4.5 mm, the aneurysm is intracranial (encircling the entire posterior circulation and aneurysms at or distal to the superior hypophyseal artery in the anterior circulation)</td>
<td>Neuroform™ Atlas stent and approved coils</td>
<td>201 enrolled patients (182 included in 12 mon analysis) in SSED: 100% occlusion, without retreatment or significant stenosis: 84.7% (95% CI, 78.6, 90.9) Any serious adverse event: 51 (28%) Cerebrovascular event: 18 (11%) unruptured Any Major Ipsilateral Stroke or Neurologic Death: 4.4% (95% CI, 1.9, 8.5)</td>
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<td>US LVIS™ pivotal trial: Fiorella et al (2018) [27]FDA SSED [73]</td>
<td>Prospective, multicenter (21 sites)</td>
<td>153 patients with unruptured or ruptured (&gt;30 days since occurrence) wide-necked (neck ≥4 mm or dome to neck)</td>
<td>LVIS™ devices</td>
<td>153 included in 12 mon analysis in SSED: 100% occlusion, without retreatment or significant stenosis: 71% (95% CI, 63 to 77)</td>
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<td>Study</td>
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<tr>
<td>Feng et al (2016)</td>
<td>Retrospective case series</td>
<td>97 patients with intracranial saccular aneurysms (13 with rupture)</td>
<td>Endovascular treatment with LVIS™</td>
<td>100% of patients had technically successful treatment; 98.9% met the primary end point of safety (absence of new transient or permanent neurologic deficit or death); Over mean 7.8-mo FU, no patient had new neurologic deterioration or died; Among 76 patients with DSA at FU, 59.21% had complete occlusion</td>
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<tr>
<td>Aydin et al (2015)</td>
<td>Retrospective case series</td>
<td>80 patients with wide-necked intracranial aneurysm (3 institutions)</td>
<td>Endovascular treatment with stent placement (Leo Baby stent)</td>
<td>97.5% of patients had technically successful treatment; 7.5% had periprocedural or delayed thromboembolic events; 3 (3.8%) had permanent neurologic deficits</td>
</tr>
<tr>
<td>Chalouhi et al (2013)</td>
<td>Retrospective case series</td>
<td>76 patients with PCA aneurysms (1 institution)</td>
<td>Of 71 successful interventions: endovascular coiling (n=60) with or without Neuroform™ stent assistance (n=4)</td>
<td>93.4% of patients had technically successful treatment; remaining patients</td>
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<tr>
<td>Study</td>
<td>Study Type</td>
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| Chen et al (2013) 77  | Retrospective case series      | 10 patients with large and giant fusiform aneurysms of the vertebrobasilar   | Endovascular treatment with stent placement (Neuroform” or Leo self-expanding, 5 patients), stent-assisted coiling (3 patients), or occlusion of proximal artery (2 patients) | • 9 patients had good outcomes; 1 patient died after stenting procedure  
  • Stent deployment was generally feasible in the vertebrobasilar system  
  • Among 67 patients who had successful endovascular treatments and who did not die in the hospital, 85% favorable outcomes (mild, moderate, no disability)                                                                                                                                   |
| Gentric et al (2013) 78 | Prospective cohort; industry-sponsored | 107 patients with unruptured cerebral aneurysms (1 of 10 European institutions) | Endovascular treatment with Neuroform™ stent-assisted coiling | • 94.4% of patients had technically successful treatment; 66.4% of patients had complete occlusion immediately postprocedure  
  • At 12- to 18-mo FU, 5 (5%) had delayed complications, with 3% having thromboembolic events. Of 93 patients with anatomic evaluation available, aneurysms recurred in 9.7%                                                                                                                                                   |
| Johnson et al (2013) 79 | Retrospective case series      | 91 patients with complex MCA aneurysms not amenable to coiling enrolled (1 institution) | Endovascular treatment with coiling with stent assistance using Neuroform” (62 aneurysms), Enterprise” (32 aneurysms), Wingspan” (1 aneurysm), or a combination (5 aneurysms) or stenting alone (2 aneurysms) | • 100% of patients had technically successful treatment  
  • 9 patients had new neurologic symptoms after procedure, 1 with long-term disability. One procedure-related death.                                                                                                              |
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<th>Study</th>
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<tr>
<td>Kulcsar et al (2013)</td>
<td>Retrospective case series</td>
<td>117 patients with wide-necked cerebral aneurysms</td>
<td>Endovascular treatment with Neuroform™ stent-assisted coiling</td>
<td>- Of 85 aneurysms with initial FU imaging available (usually at 6 mo postprocedure), 77 (90.6%) were completely occluded and 4 (4.7%) required retreatment</td>
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<td>- Stents successfully deployed in 113 patients with 117 aneurysms; 99 patients had grade 1 or 2 occlusion (complete or aneurysm neck) on immediate postprocedure imaging</td>
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<td>- Intraprocedure major thrombotic events occurred in 7 (5.9%) and major infarcts on postprocedure imaging in 9 (7.7%)</td>
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<td>- Of 92 aneurysms with FU imaging available, 71 (77%) had grade 1 or 2 occlusion</td>
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DSA: digital subtraction angiography; FU: follow-up; LVIS™: low-profile visualized intraluminal support; IDE: Investigational Device Exemption; MCA: middle cerebral artery; PCA: posterior cerebellar artery; US: United States

**Subsection Summary: Self-Expanding Stent-Assisted Coiling for Intracranial Aneurysms**

There is a lack of RCT evidence on the efficacy of self-expanding stent-assisted coiling compared with coiling alone or surgical clipping for the treatment of intracranial aneurysms. Nonrandomized studies have reported higher complete occlusion rates with stenting and lower recurrence rates. However, some evidence has shown that adverse event rates are relatively high with stenting, and one nonrandomized comparative trial reported higher mortality with stent-assisted coiling than with coiling alone. This evidence is insufficient to determine whether stent-assisted coiling improves outcomes for patients with intracranial aneurysms because the risk-benefit ratio cannot be adequately defined. However, it is recognized that patients who are candidates for endovascular therapy for aneurysms frequently have aneurysms in locations not amenable to surgical therapy, making comparisons with surgical therapy unlikely. Given the relative rarity of intracranial aneurysms, there may be legitimate barriers to clinical trials.

**Flow-Diverting Stents for Intracranial Aneurysms**

**Pivotal Studies for FDA Approval**

In 2011, the Pipeline® Embolization Device, which is categorized as a flow-diverting stent, received the FDA premarket approval. The device’s approval was based on the industry-
sponsored Pipeline® for Uncoilable or Failed Aneurysms study, a multicenter, prospective, single-arm trial (2013) of the device for treatment of internal carotid artery aneurysms that were uncoilable or had failed coiling.\textsuperscript{11} Investigators enrolled 108 patients at 10 centers with unruptured large- or giant-necked aneurysms measuring at least 10 mm in diameter, with aneurysm necks of at least 4 mm, who underwent placement of 1 or more Pipeline® devices. One patient was excluded from evaluations of the device effectiveness and safety due to unsuccessful catheterization. Four patients were excluded from the evaluation of the device effectiveness. Two patients had 2 qualifying aneurysms treated, so the “effectiveness cohort” was 106 aneurysms in 104 patients. Seventy-eight (73.6%) of 106 aneurysms met the study’s combined primary effectiveness end point of complete occlusion at day 180 without major stenosis or use of adjunctive coils. For 6 (5.6%) of the 107 patients who underwent any catheterization, a primary safety endpoint (occurrence of major ipsilateral stroke or neurologic death at 180 days) occurred.

The Surpass Streamline Flow Diverter received the FDA premarket approval in 2018. According to the FDA documentation, the Surpass diverter has the same mechanism of action as the Pipeline® diverter. The device was approved based on the pivotal Surpass Intracranial Aneurysm Embolization System Pivotal Trial to Treat Large or Giant Wide Neck Aneurysms (SCENT) prospective, single-arm study.\textsuperscript{9,81} Patients were enrolled and treated between 2012 and 2015 at 25 sites in the U.S. and 1 site in the Netherlands. Two-hundred and thirty-six patients had been enrolled and 180 had 1-year data included in the FDA report. Eligible patients had a single targeted intracranial aneurysm located in the internal carotid artery distribution up to the terminus with a neck ≥ 4 mm or no discernible neck and an aneurysm size ≥ 10 mm (including saccular, fusiform and dissecting configuration) and had a vessel diameter between 2.5 mm and 5.3 mm at both the proximal and distal segments. The incidence of major ipsilateral stroke defined as an increase in the National Institutes of Health Stroke Scale score from baseline by ≥ 4 points during stroke event or neurological death 10.6% (19/180, 95% CI, 6.5 to 16.0). Five of the patients experiencing major ipsilateral stroke also suffered neurological death. The percent of patients experiencing disabling stroke defined as modified Rankin Scale of 3 or higher measured at least 90 days after stroke event was 6.1% (11/180, 95% CI, 3.1 to 10.7). Forty-one (22.8%) of patients had improved modified Rankin Scale scores at 12-months compared to baseline. The percent of patients with 100% occlusion (Raymond-Roy Class I) without clinically significant stenosis (clinically significant stenosis defined as > 50% stenosis) of the parent artery was 62.8% (113/180).

**Review of Evidence**

**Randomized Controlled Trials**

No randomized trials evaluating intracranial aneurysms were identified comparing flow-diverting stent treatment with standard neurosurgical treatment (i.e., surgical clipping or endovascular coils) from the time of the FDA approval of the first flow-diverter until 2017.\textsuperscript{82} Raymond et al (2017) reported on results of the Flow Diversion in the Treatment of Intracranial Aneurysm Trial (FIAT).\textsuperscript{82} FIAT was an investigator-initiated, pragmatic, multicenter RCT and registry study integrated into clinical practice at 3 Canadian hospitals enrolling 112 patients, between May 2011 and February 2015. Seventy-eight patients were randomized (39 in each group) to flow diversion or standard management (physician’s choice of observation, coil embolization, parent vessel occlusion, or clip placement), and 34 additional patients received flow diversion within the registry. Inclusion criteria were pragmatic; patients with an aneurysm for which flow diversion was considered a promising treatment were eligible unless they had a contra-indication. The trial was originally powered to include 200 patients in the pilot phase and 250 patients in the pivotal phase but was stopped early due to safety concerns. Patient mean age was about 58 years, mean aneurysm size was approximately 16 mm in the RCT arm and 19 mm in the registry arm, and mean aneurysm neck was 5 mm. Approximately two-thirds of the aneurysms were in the proximal carotid, 13% were in another anterior location, and 18% were in posterior circulation. The physician’s choice in the standard care group (selected at the time of randomization) was coil embolization (with or without stent placement) in 25 (64%) patients,
parent vessel occlusion in 10 (26%) patients, observation in 4 (10%) patients, and surgical clipping in no patients. Twelve (16%) of 75 patients (95% CI, 9% to 27%) who were allocated to or received flow diversion were dead (n=8) or dependent (n=4) at 3 months or more, which crossed a predefined safety boundary. In the RCT portion of the study, morbidity or mortality occurred in 5 patients in the flow diversion group (13% 95% CI, 5% to 29%) and in 5 patients in the standard treatment group (13% 95% CI, 5% to 28%). The primary efficacy outcome was a composite including complete or near-complete occlusion of the aneurysm between 3 and 12 months and an independent functional outcome (modified Rankin Scale score ≤2). Sixteen (42%) patients (95% CI, 27% to 59%) in the flow diversion group failed to reach the primary outcome compared with 14 (36%) patients in the standard treatment group (95% CI, 22% to 53%). Characteristics of the trial is shown in Table 4. Results shown in Table 5 include all patients and the subset of patients with proximal carotid aneurysms.

Kiselev et al (2018) reported results of the Study of complex intracranial aneurysms treatment (SCAT) RCT of flow diversion versus parent vessel occlusion and bypass in patients with complex anterior circulation aneurysms conducted in 2 neurosurgical centers in Russia. One hundred eleven patients were randomized; 55 into the flow diversion group and 56 into parent vessel occlusion with bypass group. There was a baseline imbalance with respect to age and aneurysm neck size, so the authors included only 40 patients in each group who were selected after propensity score matching. Mean age was 54 years old and approximately three-quarters of the patients were women. Patients were followed for 12 months. The aneurysms were in the following segments: A2 segment of anterior cerebral artery (n=1), anterior communicating artery (n=3), cavernous carotid (n=29), ophthalmic segment of internal carotid artery (n=9), communicating segment of internal carotid artery (n=11), M1 segment (n=20) and M2 segment of middle cerebral artery (n=7). The median aneurysm size by MRI was 12 mm (interquartile range, 9 to 16.75) in bypass group and 15 mm (interquartile range, 9 to 20.5) in group of flow diversion. Study characteristics are shown in Table 8 and results are shown in Table 9. Outcome definitions were unclear. Of the 40 patients included in analysis, 97.5% in the flow diversion group and 80% in the bypass group had a ‘good clinical outcome’ (difference between groups, p=0.029). The overall morbidity and mortality rates were 15% and 5%, respectively but rates by group were not reported. The rate of complete occlusion at 12 months was 65% in the flow diversion group and 97.5% in bypass group (p=0.001).

Table 8. Summary of RCT Characteristics of Flow-Diverting Stents for Intracranial Aneurysms

<table>
<thead>
<tr>
<th>Study; Trial</th>
<th>Countries</th>
<th>Sites</th>
<th>Dates</th>
<th>Participants</th>
<th>Interventions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Raymond et al (2017) [82](FIAT; NCT01349582)</td>
<td>Canada</td>
<td>3</td>
<td>2011 to 2015</td>
<td>Patients with an aneurysm for which flow diversion was considered a promising treatment (clinical judgment)</td>
<td>N=39 Arterial (not intraaneurysmal) flow-diverting device with or without coil embolization N=39 Best standard treatment selected according to clinical judgment</td>
</tr>
<tr>
<td>Kiseleva et al (2018) [83](SCAT; NCT03269942)</td>
<td>Russia</td>
<td>2</td>
<td>2015 to 2017</td>
<td>Patients with anterior circulation complex aneurysms with neck wider than 4 mm, where dome/neck ratio ≤2:1; suitable for flow diversion and occlusion with bypass; not eligible for coiling or direct clipping</td>
<td>N=55 Flow diversion: multiple flow-diverting devices used N=56 Parent vessel occlusion and bypass</td>
</tr>
</tbody>
</table>

RCT: randomized controlled trial.
### Table 9. Summary of RCT Results of Flow-Diverting Stents for Intracranial Aneurysms

<table>
<thead>
<tr>
<th>Study (Trial)</th>
<th>Primary Efficacy Outcome</th>
<th>Death</th>
<th>Any Stroke</th>
<th>Complications</th>
<th>Residual Aneurysm or complete occlusion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Raymond et al (2017) [82] (FIAT)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>N</td>
<td>77</td>
<td>77</td>
<td>77</td>
<td>77</td>
<td>77</td>
</tr>
<tr>
<td>Flow diversion (95% CI), %</td>
<td>58 (41 to 73)a</td>
<td>5 (1 to 19)</td>
<td>13 (5 to 29)</td>
<td>29 (16 to 46)</td>
<td>18 (8 to 35)</td>
</tr>
<tr>
<td>Standard treatment (95% CI), %</td>
<td>64 (47 to 78)a</td>
<td>5 (1 to 19)</td>
<td>10 (3 to 25)</td>
<td>10 (3 to 25)</td>
<td>21 (10 to 37)</td>
</tr>
<tr>
<td>Treatment effect (95% CI)</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
</tr>
</tbody>
</table>

#### Patients with proximal carotid aneurysms

| N | 54 | 54 | 54 | 54 | 54 |
| Flow diversion (95% CI), % | 42 (NR)a | 4 (NR) | 8 (NR) | 39 (NR) | 12 (NR) |
| Standard treatment (95% CI), % | 36 (NR)a | 4 (NR) | 11 (NR) | 14 (NR) | 21 (NR) |

#### Kiseleva et al (2018) [83]

| N | 80 | 80 |
| Flow diversion (95% CI), % | 97.5b | NR by group | 5 | 65 |
| Bypass treatment (95% CI), % | 80b | 22.5 | 97.5 |
| Treatment effect (95% CI) | NR; p=0.029 | NR; p=0.048 | NR; p<0.01 |

CI: confidence interval; NR: not reported; SAE: serious adverse event; RCT: randomized controlled trial.

- The primary efficacy outcome was a composite of complete or near-complete occlusion of the aneurysm between 3 and 12 months and an independent functional outcome (mRS score ≤2).
- The primary outcome was 'good' or 'acceptable' clinical outcome. It was variably defined as neurological deterioration and neurological morbidity defined as mRS score increase by more than 1 or mRS ≥ 4.

Study limitations related to relevance and to design and conduct of trials of flow-diverting stents are shown below in Tables 10 and 11 respectively. FIAT was a pragmatic trial and as such, the population included both on- and off-label aneurysms, allowed multiple flow divertors and best standard therapy comparator as per clinical judgment.

### Table 10. Relevance Gaps of RCTs of Flow-Diverting Stents for Intracranial Aneurysms

<table>
<thead>
<tr>
<th>Study</th>
<th>Population</th>
<th>Intervention</th>
<th>Comparator</th>
<th>Outcomes</th>
<th>Follow-Up</th>
</tr>
</thead>
<tbody>
<tr>
<td>Raymond et al (2017) [82] (FIAT)</td>
<td>1. Population included both on-label and off-label use and several anatomic locations</td>
<td>1. Multiple flow-divertors were allowed</td>
<td>1. Best standard therapy not clearly defined</td>
<td>1: Key morbidity and mortality outcomes not reported by group</td>
<td>2. Death and dependency reported at 3 mon</td>
</tr>
</tbody>
</table>

| Kiseleva et al (2018) [83] | 1. Multiple flow-divertors were allowed | 1: Key morbidity and mortality outcomes not reported by group |
RCT: randomized controlled trial.

The evidence gaps stated in this table are those notable in the current review; this is not a comprehensive gaps assessment.

d Data Completeness key: 1. High loss to follow-up or missing data; 2. Inadequate handling of missing data; 3. High number of crossovers; 4. Inadequate handling of crossovers; 5. Inappropriate exclusions; 6. Not intent to treat analysis (per protocol for noninferiority trials).

Nonrandomized Comparative Studies
Zhou et al (2015) reported on results of a systematic review of studies comparing flow-diverting devices with endovascular coiling for intracranial aneurysms, which included 9 retrospective comparative studies (total n=863 subjects).84 Reviewers included studies of patients with ruptured or unruptured aneurysms. Across the 9 studies, 305 patients were treated with flow-diverting devices, 558 with coil embolization therapy, and 324 with stent-assisted coiling alone. In the pooled analysis, the use of flow-diverting devices was associated with a significantly higher complete occlusion rate than coil embolization therapy (OR=3.13; 95% CI, 2.11 to 4.65; I²=18%) or stent-assisted coiling (OR=2.08; 95% CI, 1.34 to 3.24; I²=0%). Rates of overall morbidity did not differ significantly between patients treated with flow-diverting devices and coil embolization therapy or between flow-diverting devices and stent-assisted coiling. Xin et al (2019) reported results of a similar systematic review of 11 observational studies several of which overlap with
Zhou. Results with respect to occlusion rate compared to coil embolization and mortality were similar.

**Subsection Summary: Flow-Diverting Stents for Intracranial Aneurysms**

Two RCTs have evaluated flow-diverting stents. The FIAT pragmatic RCT and registry study compared flow diversion with standard management (observation, coil embolization, or parent vessel occlusion) in patients for whom flow diversion was considered a promising treatment. FIAT was stopped early due to safety concerns after 112 participants (78 in the randomized part of the study and 34 in the registry) were enrolled. Sixteen percent of patients who were randomized to flow diversion or received flow diversion at any time were dead or dependent at 3 months or later, which crossed a predefined safety boundary. The efficacy of flow diversion was also below expectations. While morbidity and mortality were lower for proximal carotid aneurysms than for posterior circulation aneurysms and results of flow diversion were more encouraging for aneurysms amenable to coil embolization, patients allocated to standard treatment appeared to do at least as well as those assigned to flow diversion.

SCAT compared flow diversion to parent vessel occlusion and bypass in patients with complex anterior circulation aneurysms. The publication included analysis of only 80 of the 111 randomized patients. Outcome definitions were unclear in the publication. Of the patients included in analysis, ‘good clinical outcome’ was higher in the flow diversion group. Rates of overall morbidity and mortality were not reported by group. The rate of complete occlusion at 12 months was higher in the bypass group.

One nonrandomized study, which compared the flow-diverting stents with endovascular coiling for intracranial aneurysms, demonstrated higher rates of aneurysm obliteration in those treated with the Pipeline® endovascular device than in those treated with coiling, with similar rates of good clinical outcomes. Single-arm series have suggested there are high rates (≥70%) of aneurysmal occlusion after flow-diverting stent placement. As for self-expanding stents for aneurysms, patients who are candidates for endovascular therapy for aneurysms frequently have aneurysms in locations amenable to surgical therapy, making comparisons with surgical therapy unlikely.

**Summary of Evidence**

For individuals who have a acute ischemic stroke due to occlusion of an anterior circulation vessel who receive endovascular mechanical embolectomy, the evidence includes randomized clinical trials (RCTs) comparing endovascular therapy with standard care and systematic reviews of these RCTs. Relevant outcomes are overall survival, morbid events, functional outcomes, and treatment-related mortality and morbidity. From 2013 to 2015, 8 RCTs were published comparing endovascular therapies with noninterventional care for acute stroke in patients with anterior circulation occlusions. Several trials that were ongoing at the time of publication of these 8 RCTs were stopped early and results with the limited enrollment have been published. Trials published from 2014 to 2015 demonstrated a significant benefit regarding reduced disability at 90 days posttreatment. The trials that demonstrated a benefit for endovascular therapy either exclusively used stent retriever devices or allowed the treating physician to select a device, mostly a stent retriever device, and had high rates of mechanical embolectomy device use in patients randomized to endovascular therapy. Studies that demonstrated a benefit for endovascular therapy required demonstration of a large vessel, anterior circulation occlusion for enrollment. Also, they were characterized by fast time-to-treatment. Two trials published in 2018 demonstrated that it was possible to extend the window for mechanical thrombectomy up to about 24 hours for select patients. To achieve results in real-world settings similar to those in the clinical trials, treatment times, clinical protocols, and patient selection criteria should be similar to those in the RCTs. The evidence is sufficient to determine that the technology results in a meaningful improvement in the net health outcome.

For individuals who have a acute ischemic stroke due to basilar artery occlusion who receive endovascular mechanical embolectomy, the evidence includes an RCT. Relevant outcomes
are overall survival, morbid events, functional outcomes, and treatment-related mortality and morbidity. The RCT was terminated early due to high crossovers and poor recruitment. There was not a statistically significant difference in the proportion of participants with modified Rankin Scale 0–3 at 90 days or in 90 day mortality rates in the endovascular and standard therapy groups. Additional RCTs are ongoing. The evidence is insufficient to determine the effects of the technology on health outcomes.

For individuals who have symptomatic intracranial arterial stenosis who receive intracranial percutaneous transluminal angioplasty with or without stenting, the evidence includes two RCTs and a number of nonrandomized comparative studies and case series. Relevant outcomes are overall survival, symptoms, morbid events, functional outcomes, and treatment-related mortality and morbidity. Both available RCTs have demonstrated no significant benefit with endovascular therapy. In particular, the Stenting and Aggressive Medical Management for Preventing Recurrent Stroke in Intracranial Stenosis (SAMMPRIS) trial was stopped early due to harms, because the rate of stroke or death at 30 days posttreatment was higher in the endovascular arm, which received percutaneous angioplasty with stenting. Follow-up of SAMMPRIS subjects has demonstrated no long-term benefit from endovascular therapy. Although some nonrandomized studies have suggested a benefit from endovascular therapy, the available evidence from 2 RCTs does not suggest that intracranial percutaneous transluminal angioplasty with or without stenting improves outcomes for individuals with symptomatic intracranial stenosis. The evidence is sufficient to determine that the technology is unlikely to improve the net health outcome.

For individuals who have intracranial aneurysm(s) who receive endovascular coiling with intracranial stent placement or intracranial placement of a flow-diverting stent, the evidence includes RCTs, several nonrandomized comparative studies, and multiple single-arm studies. Relevant outcomes are overall survival, morbid events, functional outcomes, and treatment-related mortality and morbidity. The available nonrandomized comparative studies have reported occlusion rates for stent-assisted coiling that are similar to or higher than coiling alone and recurrence rates that may be lower than those for coiling alone. For stent-assisted coiling with self-expanding stents, some evidence has also shown that adverse event rates are relatively high, and a nonrandomized comparative trial has reported that mortality is higher with stent-assisted coiling than with coiling alone. For placement of flow-diverting stents, a pragmatic RCT and registry study have compared flow diversion with standard management (observation, coil embolization, or parent vessel occlusion) in patients for whom flow diversion was considered a promising treatment. The pragmatic study was stopped early after crossing a predefined safety boundary when 16% of patients treated with flow diversion were dead or dependent at three months or later. Flow diversion was also not as effective as the investigators had hypothesized. A nonrandomized study comparing the flow-diverting stents with endovascular coiling for intracranial aneurysms has demonstrated higher rates of aneurysm obliteration in those treated with the Pipeline® endovascular device than those treated with coiling, with similar rates of good clinical outcomes. The evidence does not provide high certainty whether stent-assisted coiling or placement of a flow-diverting stent improves outcomes for patients with intracranial aneurysms because the risk-benefit ratio cannot be adequately defined. 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.

2014 Input  
In response to requests from Blue Cross Blue Shield Association, input was received from 4 physician specialty societies and 2 academic medical centers in 2014. Input focused on the use
of flow-diverting stents such as the Pipeline® Embolization Device for the treatment of intracranial aneurysms. There was general support for the use of intracranial stent placement for intracranial aneurysms meeting the criteria outlined in the policy statements. There was also general support for the use of flow-diverting stents for the treatment of intracranial aneurysms and general support for the statement that flow-diverting stents are preferable to other stents for certain aneurysm characteristics.

There was general support for the use of endovascular interventions for the treatment of acute stroke, particularly for patients: (1) patients who have failed to respond to intravenous tissue plasminogen activator; and (2) patients who present outside the range of time for which tissue plasminogen activator would be considered (≤8 hours of last known normal state or symptom onset).

2011 Input
In response to requests from Blue Cross Blue Shield Association, input was received from 3 physician specialty societies and 3 academic medical centers in 2011. For treatment of intracranial stenosis, most providing input would consider the use of this technology in selected patients who remained symptomatic from intracranial atherosclerotic disease, despite maximum medical therapy. There was unanimous support for the use of this technology in select patients with intracranial aneurysms; i.e., in those patients for whom surgical treatment is not possible and for whom endovascular treatment (coils) does not completely isolate the aneurysm.

Practice Guidelines and Position Statements
Society of Vascular and Interventional Neurology
In 2016, the Society of Vascular and Interventional Neurology published recommendations on comprehensive stroke center requirements and endovascular stroke systems of care. The recommendations were based on 5 multicenter, prospective, randomized, open-label, blinded endpoint clinical trials that demonstrated the benefits of endovascular therapy with mechanical thrombectomy in acute ischemic strokes with large vessel occlusions. Their recommendation pertinent to this evidence review is:

"Endovascular mechanical thrombectomy, in addition to treatment with IV tissue plasminogen activator (tPA) [intravenous tissue plasminogen activator] in eligible patients, is recommended for anterior circulation large vessel occlusion ischemic strokes in patients presenting within 6 h of symptom onset."

American Heart Association and American Stroke Association
In 2018, the American Heart Association and the American Stroke Association (update 2019) published joint guidelines on the early management of patients with acute ischemic stroke. These guidelines included several recommendations relevant to the use of endovascular therapies for acute stroke.

Table 12. Recommendations on Use of Endovascular Therapies to Manage Acute Stroke

<table>
<thead>
<tr>
<th>Recommendation</th>
<th>COR</th>
<th>LOE</th>
</tr>
</thead>
<tbody>
<tr>
<td>“Mechanical thrombectomy requires the patient to be at an experienced stroke center with rapid access to cerebral angiography, qualified neurointerventionists, and a comprehensive periprocedural care team. Systems should be designed, executed, and monitored to emphasize expeditious assessment and treatment. Outcomes for all patients should be tracked. Facilities are encouraged to define criteria that can be used to credential individuals who can perform safe and timely intra-arterial revascularization procedures.”</td>
<td>I</td>
<td>C</td>
</tr>
</tbody>
</table>
| “Patients should receive mechanical thrombectomy with a stent retriever if they meet all the following criteria:  
  "Prestroke mRS score 0 to 1,  
  "Causative occlusion of the internal carotid artery or MCA (M1)," | I   | A   |
**Recommendation**

<table>
<thead>
<tr>
<th><strong>Endovascular Procedures for Intracranial Arterial Disease (Atherosclerosis and Aneurysms)</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Recommendation</strong></td>
</tr>
<tr>
<td>&quot;Age ≥18 years, NIHSS score of ≥ 6, ASPECTS of ≥6, and Treatment can be initiated (groin puncture) within 6 hours of symptom onset.&quot;</td>
</tr>
<tr>
<td>In selected patients with acute ischemic stroke within 6 to 16 hours of last known normal who have LVO in the anterior circulation and meet other DAWN or DEFUSE 3 eligibility criteria, mechanical thrombectomy is recommended.</td>
</tr>
<tr>
<td>The technical goal of the thrombectomy procedure should be a reperfusion to a modified TICI 2b/3 angiographic result to maximize the probability of a good functional clinical outcome.</td>
</tr>
<tr>
<td>As with intravenous alteplase, reduced time from symptom onset to reperfusion with endovascular therapies is highly associated with better clinical outcomes. To ensure benefit, reperfusion to TICI grade 2b/3 should be achieved as early as possible and within the therapeutic window.</td>
</tr>
<tr>
<td>&quot;Use of stent retrievers is indicated in preference to the MERCi® device. The use of mechanical thrombectomy devices other than stent retrievers may be reasonable in some circumstances.&quot;</td>
</tr>
<tr>
<td>&quot;The use of proximal balloon guide catheter or a large bore distal access catheter rather than a cervical guide catheter alone in conjunction with stent retrievers may be beneficial. Future studies should examine which systems provide the highest recanalization rates with the lowest risk for nontarget embolization.&quot;</td>
</tr>
<tr>
<td>In selected patients with AIS within 16 to 24 hours of last known normal who have LVO in the anterior circulation and meet other DAWN eligibility criteria, mechanical thrombectomy is reasonable.</td>
</tr>
<tr>
<td>&quot;In carefully selected patients with anterior circulation occlusion who have contraindications to intravenous r-TPA, endovascular therapy with stent retrievers completed within 6 hours of stroke onset is reasonable. There are inadequate data available at this time to determine the clinical efficacy of endovascular therapy with stent retrievers for those patients whose contraindications are time-based or nontime based (e.g., prior stroke, serious head trauma, hemorrhagic coagulopathy, or receiving anticoagulant medications).&quot;</td>
</tr>
<tr>
<td>Although the benefits are uncertain, use of mechanical thrombectomy with stent retrievers may be reasonable for carefully selected patients with acute ischemic stroke in whom treatment can be initiated (groin puncture) within 6 hours of symptom onset and who have causative occlusion of the M2 or M3 portion of the MCAs.</td>
</tr>
<tr>
<td>Although the benefits are uncertain, use of mechanical thrombectomy with stent retrievers may be reasonable for carefully selected patients with acute ischemic stroke in whom treatment can be initiated (groin puncture) within 6 hours of symptom onset and who have causative occlusion of the anterior cerebral arteries, vertebral arteries, basilar artery, or posterior cerebral arteries.</td>
</tr>
<tr>
<td>Although the benefits are uncertain, use of mechanical thrombectomy with stent retrievers may be reasonable for patients with acute ischemic stroke in whom treatment can be initiated (groin puncture) within 6 hours of symptom onset and who have prestroke mRS score of ≥1, ASPECTS &lt;6, or NIHSS score &lt;6 and causative occlusion of the internal carotid artery or proximal MCA (M1). Additional randomized trial data are needed.</td>
</tr>
<tr>
<td>In patients under consideration for mechanical thrombectomy, observation after IV alteplase to assess for clinical response should not be performed.</td>
</tr>
<tr>
<td>&quot;Use of salvage technical adjuncts including intra-arterial fibrinolysis may be reasonable to achieve these angiographic results&quot;</td>
</tr>
<tr>
<td>&quot;Intra-arterial fibrinolysis initiated within 6 hours of stroke onset in carefully selected patients who have contraindications to the use of intravenous alteplase might be considered, but the consequences are unknown.&quot;</td>
</tr>
</tbody>
</table>
The 2 associations also published joint guidelines on the management of patients with unruptured intracranial aneurysms in 2015. These guidelines included the following recommendations relevant to the use of endovascular therapies for aneurysms (see Table 13).

### Table 13. Recommendations on Management of Unruptured Intracranial Aneurysms

<table>
<thead>
<tr>
<th>Recommendation</th>
<th>COR</th>
<th>LOE</th>
</tr>
</thead>
<tbody>
<tr>
<td>“...coil embolization may be superior to surgical clipping with respect to procedural morbidity and mortality, length of stay, and hospital costs, so it may be reasonable to choose endovascular therapy over surgical clipping in the treatment of select unruptured intracranial aneurysms, particularly in cases for which surgical morbidity is high, such as at the basilar apex and in the elderly”</td>
<td>Iib</td>
<td>B</td>
</tr>
<tr>
<td>“...coil embolization may be superior to surgical clipping with respect to procedural morbidity and mortality, length of stay, and hospital costs, so it may be reasonable to choose endovascular therapy over surgical clipping in the treatment of select unruptured intracranial aneurysms, particularly in cases for which surgical morbidity is high, such as at the basilar apex and in the elderly”</td>
<td>Iib</td>
<td>B</td>
</tr>
<tr>
<td>“Endovascular treatment of unruptured intracranial aneurysms is recommended to be performed at high-volume centers.”</td>
<td>I</td>
<td>B</td>
</tr>
</tbody>
</table>

U.S. Preventive Services Task Force Recommendations

No U.S. Preventive Services Task Force recommendations for treatment of intracranial arterial disease were identified. The U.S. Preventive Services Task Force has recommended against screening for asymptomatic carotid artery stenosis in the general population.

### Medicare National Coverage

A Medicare national coverage determination on intracranial angioplasty and stenting was released by the Centers for Medicare & Medicaid Services in 2008. This decision was based on a review of available studies at that time, which consisted of several uncontrolled case series. The Centers for Medicare & Medicaid Services review indicated that this evidence was promising and that, while further well-designed randomized controlled trials were needed to confirm whether outcomes were improved, coverage should be allowed. The national coverage determination contained the following coverage determinations:

1. Medicare coverage for angioplasty and/or stenting for symptomatic patients with greater than 70 percent intracranial arterial stenosis, and
2. Medicare coverage for intracranial angioplasty and/or stenting for other patients within the context of Category B investigational device exemption trials under coverage with evidence development within a registry.

### Ongoing and Unpublished Clinical Trials

Some currently unpublished trials that might influence this review are listed in Table 14.

### Table 14. Summary of Key Trials

<table>
<thead>
<tr>
<th>NCT No.</th>
<th>Trial Name</th>
<th>Planned Enrollment</th>
<th>Completion Date</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Endovascular interventions for acute ischemic stroke</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Ongoing</td>
<td></td>
<td></td>
</tr>
<tr>
<td>NCTNo.</td>
<td>Trial Name</td>
<td>Planned Enrollment</td>
<td>Completion Date</td>
</tr>
<tr>
<td>-------------</td>
<td>-----------------------------------------------------------------------------</td>
<td>--------------------</td>
<td>-----------------</td>
</tr>
<tr>
<td>NCT02216643</td>
<td>Randomization of Endovascular Treatment With Solitaire FR® vs. Best Medical Therapy in Acute Ischemic Stroke Due to Large Vessel Occlusion Trial (RESILIENT)</td>
<td>221 (actual)</td>
<td>Jun 2019</td>
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<td>NCT01717755</td>
<td>Basilar Artery International Cooperation Study (BASICS)</td>
<td>282</td>
<td>Jan 2020</td>
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<td>NCT02737189</td>
<td>Randomized Trial of Revascularization With Solitaire Stentriever Versus Best Medical Therapy in the Treatment of Acute Ischemic Stroke Due to Basilar Artery Occlusion Presenting Within 6-24 Hours of Symptom Onset</td>
<td>318</td>
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<td>NCT01455935</td>
<td>Wake up Symptomatic Stroke in Acute Brain Ischemia (WASSABI) Trial</td>
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<td></td>
<td>RECO Flow Restoration Device Versus Intravenous t-PA for Stroke Within 4.5h of Symptom Onset: a Prospective Randomized Control Trial (RESTORE)</td>
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<td>NCT01763320</td>
<td>China Angioplasty &amp; Stenting for Symptomatic Intracranial Severe Stenosis (CASSISS): A Prospective Multicenter, Randomized Controlled Trial</td>
<td>380</td>
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<td>NCT01340612</td>
<td>Stenting in the Treatment of Aneurysm Trial (STAT)</td>
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<td>NCT01340612</td>
<td>Stenting in the Treatment of Large, Wide-necked or Recurring Intracranial Aneurysms</td>
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<td>Jan 2020</td>
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<td>NCT02998229</td>
<td>ARTISSE Aneurysm Treatment Using Intracranial Flow Diversion With the ARTISSE™ Device</td>
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<td>Sep 2023</td>
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<td>NCT01762137</td>
<td>LARGE Aneurysm Randomized Trial: Flow Diversion Versus Traditional Endovascular Coiling Therapy</td>
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<td>NCT01811134</td>
<td>Flow Diverter Stent for Endovascular Treatment of Unruptured Saccular Wide-necked Intracranial Aneurysms (EVIDENCE)</td>
<td>130</td>
<td>Nov 2017</td>
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</tbody>
</table>

**Endovascular interventions for symptomatic intracranial atherosclerotic disease**

**Stent-assisted endovascular treatment of intracranial aneurysms**

**References**


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**Documentation for Clinical Review**

Please provide the following documentation:

- History and physical and/or consultation notes including:
  - Description and measurements of intracranial aneurysm(s)
- All imaging reports related to current event
- Consultation report(s) from Neurologist
- Procedure report(s) from Interventional Radiologist

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Post Service (in addition to the above, please include the following):
  - Operative report(s)

### 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.

**MN/IE**

The following services may be considered medically necessary in certain instances and investigational in others. Services may be considered medically necessary when policy criteria are met. Services may be considered investigational when the policy criteria are not met or when the code describes application of a product in the position statement that is investigational.

<table>
<thead>
<tr>
<th>Type</th>
<th>Code</th>
<th>Description</th>
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<tr>
<td>CPT</td>
<td>61630</td>
<td>Balloon angioplasty, intracranial (e.g., atherosclerotic stenosis), percutaneous</td>
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<td>61635</td>
<td>Transcatheter placement of intravascular stent(s), intracranial (e.g., atherosclerotic stenosis), including balloon angioplasty, if performed</td>
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<tr>
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<td>61640</td>
<td>Balloon dilatation of intracranial vasospasm, percutaneous; initial vessel</td>
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<td>61641</td>
<td>Balloon dilatation of intracranial vasospasm, percutaneous; each additional vessel in same vascular territory (List separately in addition to code for primary procedure)</td>
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<tr>
<td></td>
<td>61642</td>
<td>Balloon dilatation of intracranial vasospasm, percutaneous; each additional vessel in different vascular territory (List separately in addition to code for primary procedure)</td>
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<td>61645</td>
<td>Percutaneous arterial transluminal mechanical thrombectomy and/or infusion for thrombolysis, intracranial, any method, including diagnostic angiography, fluoroscopic guidance, catheter placement, and intraprocedural pharmacological thrombolytic injection(s)</td>
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**HCPCS**

None

### Policy History

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

<table>
<thead>
<tr>
<th>Effective Date</th>
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<tr>
<td>06/12/2002</td>
<td>New policy</td>
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<tr>
<td>08/23/2002</td>
<td>Policy Review</td>
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<tr>
<td>03/01/2005</td>
<td>Policy Review MPC accepted as CTAF consent; BCBSA TEC Vol. 19, No. 15.</td>
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<tr>
<td>10/01/2005</td>
<td>Policy Review Title modification</td>
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<td>12/01/2005</td>
<td>Policy revision without position change MPC accepted CTAF recommendation; policy updated, statement unchanged</td>
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<td>12/08/2008</td>
<td>Coding update</td>
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<td>12/18/2009</td>
<td>Policy revision with position change Title change from Extracranial Carotid Angioplasty and Stenting and Cerebral Angioplasty and Stenting for Atherosclerosis, Stroke and Vasospasm</td>
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<td>07/11/2011</td>
<td>Coding Update</td>
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</table>
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.