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**Type of Submission – Check all that apply:**
- [ ] New Policy
- [ ] Revised Policy
- [x] Annual Review – No Revisions*

*All revisions to the policy must be highlighted using track changes throughout the document. Please provide any clarifying information for the policy below:

**CPB 0094 Magnetic Resonance Angiography (MRA) and Magnetic Resonance Venography (MRV)**

Clinical content was last revised on 03/24/2017. No additional non-clinical updates were made by Corporate since the last PARP submission.

**Revision and Update History since last PARP Submission:**
01/25/2018 – Tentative next scheduled review date by Corporate – no updates available.

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Clinical Policy Bulletin:
Magnetic Resonance Angiography (MRA) and Magnetic Resonance Venography (MRV)

Number: 0094

Policy

*Please see amendment for Pennsylvania Medicaid at the end of this CPB.

Magnetic Resonance Angiography (MRA)

1. Aetna considers magnetic resonance angiography (MRA) medically necessary according to the selection criteria outlined below. MRA is considered appropriate when it can replace a more invasive test (e.g., contrast angiography) and reduce risk for members. While MRA is a rapidly evolving technology, its clinical safety and effectiveness for all anatomical regions have not been established by the peer-reviewed medical literature.

Head and Neck

MRA of the head and neck is considered medically necessary for any of the following conditions:

A. As a follow-up study for a known arterio-venous malformation (AVM), and for a known non-ruptured intra-cranial aneurysm (ICA) that is greater than 3 mm in size; or
B. To definitively establish presence of stenoses or other abnormalities of the vertebrobasilar system in members with symptoms highly suggestive of vertebrobasilar syndrome (binocular vision loss, diplopia, dysarthria, dysphagia, positional vertigo); or
C. To evaluate members with signs/symptoms highly suggestive of leaking/ruptured ICA or AVM (i.e., blood in the cerebral spinal fluid, stiff neck, sudden explosive headache); or
D. To evaluate pulsatile tinnitus in members with signs or symptoms suggestive of a vascular lesion; or
E. To rule out ICA, including aneurysms of the circle of Willis, in members who are thought to be at higher risk (e.g., history of ICA in a first-degree relative or presence of polycystic kidney disease); or
F. To evaluate conditions of the carotid arteries such as:

- Aneurysm tumor
- Cervicocranial arterial dissection in members with suggestive signs or symptoms (e.g., amaurosis fugax, oculo-sympathetic palsy, symptoms of focal brain ischemia, and unilateral headache)
- Injury to the carotid artery
- Stenotic/occlusive disease in asymptomatic members who are candidates for carotid endarterectomy surgery (CEA) when a Duplex Doppler scan is abnormal
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- Stenotic/occlusive disease in symptomatic members (e.g., cerebro-vascular disease or transient ischemic attack).

Note: As MRA is considered an alternative to angiography for evaluation of the carotids, a subsequent angiography would only be considered medically necessary if there was a significant discrepancy between the findings of Duplex ultrasonography and MRA that would impact on surgical planning.

**Chest**

MRA of the chest is considered medically necessary for any of the following indications:

A. For diagnosis, treatment planning, and post-operative follow-up for conditions of the thoracic aorta such as aneurysm (true or pseudoaneurysm), dissection, or stenotic/occlusive vascular disease; or
B. For diagnosis, treatment planning, and post-operative surgical shunt evaluation in members with congenital heart disease (CHD) or developmental anomalies of the thoracic vasculature (e.g., atresia or hypoplasia of the pulmonary arteries, coarctation of the aorta, double aortic arch, interrupted inferior vena cava, partial anomalous venous connection, persistent left superior vena cava, right-sided aortic arch, total anomalous pulmonary venous connection, and truncus arteriosus); or
C. For diagnosing a suspected pulmonary embolism when the use of intravascular iodinated contrast material is contraindicated, or as a substitute for pulmonary angiography when a ventilation/perfusion (V/Q) scan does not provide sufficient information for treatment decisions; or
D. For pulmonary venous and left atrial evaluation, pre- and post-radiofrequency ablation for atrial fibrillation.

**Spine**

MRA of the spinal canal is considered medically necessary for individuals with known cases of spinal cord arterio-venous fistula and arterio-venous malformation. MRA of the spinal canal is considered experimental and investigational for all other indications.

**Abdomen**

MRA of the abdomen is considered medically necessary for any of the following indications:

A. To assess the main renal arteries for the evaluation of renal artery stenosis in persons with refractory uncontrolled hypertension\* - not due to pheochromocytoma; or
B. To assess persons with sickle cell disease; or
C. To assess pelvic (e.g., aorto-iliac) arteries for stenoses in members with peripheral vascular disease; or
D. To evaluate endoleaks following endovascular repair of abdominal aortic aneurysm; or
E. To evaluate hepatic vasculature prior to transjugular intrahepatic portosystemic shunt (TIPS); or
F. To determine the extent of an abdominal aortic aneurysm and associated occlusive disease in members undergoing elective repair; or
G. To evaluate for chronic mesenteric ischemia.

Footnotes: * Refractory hypertension is defined as diastolic blood pressure consistently greater than 100 mm Hg on 3 or more blood pressure medications.

**Lower Extremity**

MRA of the lower extremities is considered medically necessary as an initial test for diagnosis and surgical planning in the treatment of peripheral arterial disease of the lower extremity. A
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subsequent angiography study is only required if the inflow vessel is not identified on the MRA. If conventional catheter angiography is performed first, doing a subsequent MRA may be indicated if a distal run-off vessel is not identified. Both tests should not be routinely performed.

Allergy, etc.

The use of MRA is considered medically necessary in members with documented allergy to iodinated contrast material, and in members who have accelerating hypertension and/or accelerating renal insufficiency.

II. Aetna considers the use of gadofosveset trisodium (Ablavar, previously marketed as Vasovist injection) an appropriate agent for medically necessary contrast-enhanced MRA of blood vessels in the abdomen and lower extremities in adults.

III. Aetna considers MRA to be experimental and investigational for all other indications because its effectiveness for indications other than the ones listed above has not been established, including any of the following:

A. Cardiac MRI for velocity flow mapping; or
B. Diagnosing cerebral arteriovenous malformations; or
C. Evaluating accessory renal arteries in prospective renal donors, including potential living kidney donors; or
D. Evaluating members with symptoms suggestive of dural, sagittal or cavernous sinus thrombosis/occlusion; or
E. Evaluating microvascular compression associated with trigeminal neuralgia; or
F. Evaluating premature ventricular contraction; or
G. Evaluating recurrent cystic hygroma of the axilla; or
H. Evaluating varices at hepatico-jejunostomy after liver transplantation; or
I. Evaluating vasa previa; or
J. Predicting pulmonary hypertension; or
K. Ruling out ICA in members who have vague central nervous system symptoms (e.g., dizziness, headache, non-specific sensory loss, or vertigo); or
L. Screening for renovascular hypertension; or
M. Screening of the general population for ICAs; or
N. Surveillance of individuals with brain cancer following radiotherapy

IV. Aetna considers ferumoxytol-enhanced MRA for evaluation of transplant renal artery stenosis experimental and investigational because its effectiveness has not been established.

Magnetic Resonance Venography (MRV)

I. Aetna considers MRV medically necessary for any of the following indications:

A. For evaluation of thrombosis or compression by tumor of the cerebral venous sinus in members who are at risk (e.g., hyper-coagulable disorders, meningitis, oral contraceptive use, otitis media, sinusitis, underlying malignant process) or have signs or symptoms (e.g., drowsiness and confusion accompanying a headache, focal motor or sensory deficits, papilledema, or seizures); or
B. For evaluation of venous thrombosis or occlusion in the large systemic veins (e.g., superior vena cava, subclavian, or other deep veins in the chest); or
C. For evaluation of venous thrombosis or occlusion in the portal and/or hepatic venous system (e.g., Budd-Chiari syndrome).

II. Aetna considers MRV experimental and investigational for diagnosis of deep vein thrombosis in the arms or legs because the peer-reviewed medical literature has not established MRV to be
superior to Duplex ultrasonography for this purpose. MRV is considered experimental and investigational for all other indications (e.g., diagnosis of chronic cerebrospinal venous insufficiency) because its effectiveness for indications other than the ones listed above has not been established.

III. Aetna considers pelvic MRV for diagnostic evaluation of cryptogenic stroke experimental and investigational because its effectiveness for this indication has not been established.

IV. Aetna considers quantitative MRV for measurement of venous flow after cerebral venous sinus stenting experimental and investigational because its effectiveness has not been established.

V. Aetna considers ferumoxytol-enhanced MRV for the diagnosis of chronic kidney disease experimental and investigational because its effectiveness has not been established.

Background

Magnetic resonance angiography (MRA) is an application of magnetic resonance imaging (MRI) that provides visualization of blood flow, as well as images of normal and diseased blood vessels. While MRA appears to be a rapidly developing technology, the clinical safety and effectiveness of this procedure for all anatomical regions has not been proven.

The use of MRA in evaluating flow in the carotid arteries, the circle of Willis, the anterior, middle or posterior cerebral arteries, the vertebral or basilar arteries, or the venous sinuses have been the most well researched applications. Numerous articles have demonstrated that MRA can image the vessels with a high degree of sensitivity and specificity. However, the appropriate use of MRA in this setting must be coordinated with the use of the competing technologies, Duplex ultrasonography and angiography. There is no mention in the literature that all 3 technologies should be used routinely in the work-up of carotid artery disease. In terms of screening patients with symptoms suggestive of disease, duplex ultrasonography has been shown to be equivalent to MRA, and thus this test is recommended as the initial diagnostic test. In terms of surgical planning, MRA has been shown to be competitive with angiography, therefore this test can be the second definitive test used for surgical planning. In this scenario, an angiography would only be considered medically necessary if the ultrasonography and MRA showed major discrepancies. Finally, in a more limited role, MRA has been suggested as an alternative to angiography in those patients unable to undergo an angiogram due to allergy to contrast material.

Patients with transient ischemic attacks or strokes typically undergo MRI as part of the initial work-up to identify infarcted areas in the brain. An intra-cranial MRA can be easily appended to the MRI and for that reason has been frequently ordered. However, an intra-cranial MRA is considered not medically necessary. MRI can adequately image any infarcted areas, and in the case of transient ischemic attacks, by definition, one would not expect to see any vascular abnormalities. The use of MRA in the work-up of patients with the vertebrobasilar syndrome must be considered on a case-by-case basis. The MRA may be appropriate in patients when other sources of emboli have been ruled out, and the MRA is considered as an alternative to an angiogram in order to establish the diagnosis of vertebral artery disease.

Although MRA provides additional imaging capabilities for intra-cranial aneurysms (ICAs) and vascular lesions, it is not clear from the literature how this information will impact on patient management. In particular, patients who present subacutely with symptoms consistent with aneurysm or vascular malformations will probably undergo a conventional spin-echo MRI followed by angiography, if indicated. It is unclear from the literature how MRA would alter this imaging hierarchy. Several authors commented that the anatomic detail provided by MRA is not sufficient to replace an angiogram. Magnetic resonance angiography has also been suggested as a novel screening technique for patients at high risk for aneurysm; however, its clinical relevance is unknown because of
a lack of understanding of the natural history of aneurysms and which aneurysms represent a high risk of rupture. Due to its low diagnostic yield, MRA is considered not medically necessary for the routine work-up of patients with non-specific, non-focal symptoms, such as headache or dizziness.

Magnetic resonance angiography is an effective non-invasive technique for establishing a diagnosis and evaluating the extent and severity of nearly all diseases of the thoracic aorta. Studies have shown that MRA of the chest has a high level of diagnostic accuracy for pre-operative and post-operative evaluation of aortic dissection of aneurysm. Depending on the clinical presentation, MRA may be used as an alternative to other non-invasive imaging technologies (e.g., trans-esophageal echocardiography and CT).

Saremi and Tafti (2009) noted that cardiac ablation procedures have become the standard of therapy for various arrhythmias including atrial fibrillation (AF). Understanding the morphological characteristics of the left atrium (LA) and pulmonary vein (PV) in detail and identification of its anatomic variants is crucial to perform a successful ablation procedure and minimize complications. The current techniques for radiofrequency ablation of AF include targeting the PVs or the tissue in the antrum of the LA. Localization of the anatomic structures within the LA is performed by using fluoroscopy, electro-anatomic mapping, and intra-cardiac echocardiography. Multi-dimensional CT and MRA are invaluable techniques for better visualization of the anatomic landmarks that are essential for cardiac ablation procedures as well as prompt diagnosis and, in selected cases, prevention of procedure-related complications. Some of the complications of ablation procedures may include cardiac tamponade, PV stenosis, as well as esophageal and phrenic nerve injuries.

Holmes et al (2009) stated that ablation procedures for AF are being performed with increasing frequency. One of the most serious complications is the development of pulmonary vein stenosis, which occurs in 1 % to 3 % of current series. The presentation of pulmonary vein stenosis varies widely. The majority of patients are asymptomatic although specific referral bias patterns can affect this. Symptoms may include dyspnea or hemoptysis or may be consistent with bronchitis. These symptoms are affected by the number of stenotic veins as well as the severity of the stenosis. The more severe the stenosis and the greater number of stenosed veins result in more symptoms. Because of the variability in symptoms, clinicians must have heightened sensitivity to the presence of the condition. Diagnostic tests of value include MRA and computed tomography. Although echocardiography has been used, it does not usually provide adequate assessment. Progression of stenosis is unpredictable and may be rapid. The specific anatomy of the stenosis varies widely and affects management. Because of the presence of antral fusion of the origin of the left superior and left inferior pulmonary vein, a stenosis involving 1 or the other can impinge and affect outcome. In this setting, bifurcation techniques familiar to interventional cardiology are very helpful. Controversy currently exists about the optimal treatment approach. The use of balloons and larger stents (approximately 10 mm) results in more optimal results than just balloon angioplasty alone; however, even with stent implantation, recurrent re-stenosis may occur in 30 % to 50 % of patients. Follow-up of these patients typically involves computed tomography imaging to document re-stenosis. If significant re-stenosis is identified, it should be treated promptly because of the potential for progression to total occlusion.

Furthermore, a CMS decision memo (2010) noted that it has received a position statement in the form of a combined comment from the American College of Cardiology (ACC), American College of Radiology (ACR), American Society of Neuroradiology (ASNR), North American Society for Cardiovascular Imaging (NASCI), and the Society for Cardiovascular Magnetic Resonance (SCMR). They were in favor of combining the currently separate NCDs, allowing local Medicare contractor discretion to cover use of MRA for additional indications which are currently non-covered, and they recommended national coverage for MRA of the pulmonary veins before and after radiofrequency ablation for AF.

Current scientific data shows that diagnostic pulmonary MRAs are improving due to recent developments such as faster imaging capabilities and gadolinium-enhancement. However, these
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Advances in MRA are not significant enough to warrant replacement of pulmonary angiography in the diagnosis of pulmonary embolism for patients who have no contraindication to receiving intravenous iodinated contrast material. The tortuous pulsatile nature of the coronary arteries presents an imposing technical challenge to MRA. The application of MRA for this purpose is still in its infancy.

Studies have proven that MRA is considered a reliable diagnostic tool for the pre-operative evaluation of patients who will undergo elective abdominal aortic aneurysm (AAA) repair. In addition, scientific data has revealed that MRA is considered comparable to conventional angiography in determining the extent of the AAA, as well as evaluation of aorto-iliac occlusion disease and renal artery pathology that may be necessary in the surgical planning for AAA repair. If pre-operative angiography is not necessary, then patients are not exposed to the risks associated with invasive contrast procedures, namely allergic reactions, end-organ damage or arterial injury. Magnetic resonance angiography has also become accepted as a method to detect suspected stenosis in the main renal arteries; its inability to image distal lesions and accessory arteries limits its diagnostic abilities.

Although MRA assessment for the evaluation of renal artery stenosis is acceptable, the accuracy of MRA as a screening method for renovascular hypertension is unproven, and MRA is inadequate in the identification of accessory renal arteries because it has not achieved the level of accuracy needed to replace conventional angiography in the evaluation of potential living renal donors.

Surgical planning for peripheral arterial occlusive disease in the lower extremities depends on identification of adequate inflow and distal run off vessels. Magnetic resonance angiography has been shown to be a superior technique in identifying distal run-off vessels and is competitive with angiography in identifying appropriate inflow vessels. Therefore, MRA can be used as an initial test for surgical planning, with a subsequent angiography only if the inflow vessel is not identified. If angiography is performed first, an MRA may be appropriate if a distal run-off vessel is not identified because MRA is capable of detecting a viable run-off vessel for bypass not seen on traditional angiography, especially when exploratory surgery is not believed to be a reasonable medical course of action for the patient.

On December 24, 2008, the United States Food and Drug Administration (FDA) approved Vasovist injection (gadofosveset trisodium, now marketed as Ablavar), the first contrast imaging agent for use in patients undergoing MRA. Gadofosveset reversibly binds to albumin providing extended intravascular enhancement compared with existing extracellular magnetic resonance contrast agents. Administration of gadofosveset provides a clearer image in patients who are suspected of having blockages or other problems with the blood vessels in their abdomen or extremities. The safety and effectiveness of Vasovist was established in 2 clinical trials of patients with known or suspected aorto-iliac disease. In the studies, patients underwent MRA with and without Vasovist and their scans were compared to standard X-ray pictures using contrast. Magnetic resonance angiography with Vasovist detected more arterial disease than MRA performed without Vasovist and the pictures were of improved technical quality.

Bosch et al (2008) evaluated the safety and effectiveness of gadofosveset in patients with pedal arterial disease. A total of 185 adult patients with known or suspected pedal arterial disease were randomized in a group receiving 0.03 mmol/kg and a group receiving 0.05 mmol/kg of gadofosveset for MRA of the pedal arteries. Gadofosveset-enhanced and unenhanced time-of-flight MR angiograms were compared with conventional angiograms for the presence of vascular stenosis. All patients underwent drug safety analysis. For each of 3 blinded readers, the specificity (21 to 35 %) of gadofosveset-enhanced MRA was a statistically significant (p < 0.010) improvement over that of unenhanced MRA in the detection of clinically significant (greater than 50 %) stenosis. The sensitivities of the 2 techniques were similar. For all blinded readers of MR angiograms, sensitivity, specificity, and accuracy were higher with use of the 0.03-mmol/kg dose of gadofosveset than with the 0.05-mmol/kg dose. In the 0.03-mmol/kg group, 28 % of patients reported a total of 50 adverse events, 96 % of which were reported as mild or moderate. In the 0.05-mmol/kg group, 28 % of patients reported a total of 55 adverse events, 98 % of which were reported as mild or moderate. No patients
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died; 1 patient left the study because of myocardial infarction considered unrelated to the study drug. The authors concluded that because of markedly better efficacy than no contrast agent and a minimal and transient side-effect profile, 0.03 mmol/kg of gadofosveset was found safe and effective for MRA of patients with pedal arterial disease.

In a multi-center, comparative, phase III single-dose clinical study, McGregor et al (2008) examined the effectiveness of gadofosveset-enhanced MRA for evaluation of renal artery disease. Gadofosveset (0.03 mmol/kg) was administered to adult patients with known or suspected renal arterial disease; the drug allows collection of images in the first-pass and steady-state phases. The combination of these images was compared to non-contrast MRA, using catheter X-ray angiography (XRA) as the standard of reference. All MRA images were collected at 1.5 T in 1 imaging session for direct comparison, and XRA within 30 days. Sensitivity, specificity, and accuracy for diagnosing significant disease (stenosis greater than or equal to 50 %) were calculated for MRA using 3 independent blinded readers. Patient safety was monitored for 72 to 96 hours. A total of 145 patients were enrolled and received gadofosveset; the 127 with complete efficacy data entered the primary efficacy analysis.

Gadofosveset-enhanced MRA led to significant improvement (p < 0.01) in sensitivity (+25 %, +26 %, +42 %), specificity (+23 %, +25 %, +29 %), and accuracy (+23 %, +28 %, +29 %) over non-enhanced MRA for the 3 readers. The rate of uninterpretable examinations decreased from 30 % to less than 2 %. There were no serious adverse events, and the most common adverse events were nausea, pruritis, and headache (8 % each). No significant trends in clinical chemistry parameters, nor significant changes in serum creatinine, were found following administration of gadofosveset. The authors concluded that in patients with known or suspected renal arterial disease, gadofosveset-enhanced MRA significantly improves sensitivity, specificity, and accuracy versus non-enhanced MRA. Gadofosveset was safe and well-tolerated in this patient population.

There is evidence that MRA, as an adjunct to conventional MRI, is useful in the evaluation of the spinal cord. Farb et al (2002) described the cases of 9 patients with initial MRI and clinical findings suggestive of spinal dural arterio-venous fistula (AVF) who underwent spinal MRA with an auto-triggered elliptic centric ordered three-dimensional (3-D) gadolinium-enhanced technique (hereafter, this MRA technique) before conventional intra-arterial angiography. In all 9 patients, findings with this MRA technique correctly and precisely localized the spinal dural AVF. Observer error resulted in 1 case in which the site of the fistula was not prospectively reported, but was easily identified retrospectively on the spinal MR angiogram.

Saraf-Lavi E et al (2002) studied the sensitivity, specificity, and accuracy of MRI alone compared with MRI plus MRA in determining whether dural AVF are present and established the accuracy of MRA in predicting fistula level. A total of 20 patients with surgically proven dural AVF (diagnosed with radiographic digital subtraction angiography) and 11 control patients who had normal digital subtraction angiography findings underwent routine MRI plus 3-D contrast-enhanced MRA of the spine. Images were reviewed in 2 stages (stage I, MRI only; stage II, MRI plus MRA) by 3 neuroradiologists who were blinded to the final diagnoses. The sensitivity, specificity, and accuracy of the 3 reviewers in detecting the presence of fistulae ranged from 85 % to 90 %, from 82 % to 100 %, and from 87 % to 90 %, respectively, for stage I, compared with values of 80 % to 100 %, 82 %, and 81 % to 94 %, respectively, for stage II. For each reviewer, there were no significant differences between the values for stage I and stage II; however, among the reviewers, one of the more experienced neuroradiologists had significantly greater sensitivity than a less experienced neuroradiologist for stage II. On average, the percentage of true positive results for which the correct fistula level was predicted increased from 15 % for stage I to 50 % for stage II, and the correct level +/- one level was predicted in 73 % for stage II. MR evidence of increased intra-dural vascularity was significantly greater in patients with dural AVF. The authors concluded that the addition of MRA to standard MRI of the spine may improve sensitivity in the detection of spinal dural fistulae. The principal benefit of MRA is in the improved localization of the vertebral level of the fistula, which potentially expedites the subsequent digital subtraction angiography study.

Luetmer et al (2005) tested the hypothesis that elliptic centric contrast-enhanced MRA can be used to
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detect spinal dural AVFs, predict the level of fistulas, and reduce the radiation dose and volume of iodinated contrast material associated with conventional angiography. These researchers examined 31 patients who presented with suspected spinal dural AVF. All patients underwent MRA and conventional angiography. The effect of MRA on subsequent conventional angiography was assessed by analyzing total fluoroscopy time and volume of iodinated contrast material used. At angiography, spinal dural AVFs were diagnosed in 22 of 31 patients, and MRA depicted an AVF in 20 of the 22 patients. Magnetic resonance angiographic findings correctly predicted a negative angiogram in 7 of 9 cases. Of the 20 true-positive MRA results, the level of the fistula was included in the imaging volume in 14. In 13 of these 14 cases, MRA results correctly predicted the side and the level of the fistula to within 1 vertebral level. Fluoroscopy time and the volume of contrast agent was reduced by more than 50% in the 13 patients with a spinal dural AVF in whom MRA prospectively indicated the correct level. The authors concluded that contrast-enhanced MRA can be used to detect spinal dural AVFs, predict the level of fistulas, and substantially reduce the radiation dose and volume of contrast agent associated with catheter spinal angiography.

Meckel et al (2007) stated that digital subtraction angiography (DSA) is the method of reference for imaging of dural AVF (DAVF). The goal of this study was to analyze the value of different MR images including 3-D contrast-enhanced MRA with a high temporal resolution in diagnostic and follow-up imaging of DAVFs. A total of 18 MR/MRA examinations from 14 patients with untreated (n = 9) and/or treated (n = 9) DAVFs were evaluated. Two observers assessed all MR and MRA investigations for signs indicating the presence of a DAVF, for fistula characteristics such as fistula grading, location of fistulous point, and fistula obliteration after treatment. All results were compared with DSA findings. On time-resolved 3-D contrast-enhanced (TR 3-D) MRA, the side and presence of all patent fistulas (n = 13) were correctly indicated, and no false-positive findings were observed in occluded DAVFs (n = 5). Grading of fistulas with this imaging technique was correct in 77% and 85% of patent fistulas for both readers, respectively. On T2-weighted images, signs indicative of a DAVF were encountered only in fistulas with cortical venous reflux (56%), whereas on 3-D time-of-flight (TOF) MRA, most fistulas (88%) were correctly detected. In complete fistula occlusion, false-positive findings were encountered on both T2-weighted images and on TOF MRA images. The authors concluded that TR 3-D MRA proved reliable in detecting DAVFs and suitable for follow-up imaging. The technique allowed -- within limitations -- to grade DAVFs. Although 3-D TOF MRA can depict signs of DAVFs, its value for follow-up imaging is limited.

Mull et al (2007) examined the validity of MRA for identification of spinal arterio-venous (AV) abnormalities. A total of 34 consecutive patients with suspicion of spinal vascular abnormalities underwent digital subtraction angiography (DSA) after MRA. The level and side of the suspected spinal DAVF (S-DAVF) and the feeding arteries in spinal AV malformations (SAVMs) were determined from MRA and compared with DSA. DSA revealed S-DAVF in 20 abnormalities of which 19 were spinal and 1 was tentorial with spinal drainage, as well as SAVM in 11 patients. In 3 patients, MRA and DSA were both normal. For detection of spinal AV abnormalities, neither false-positive nor false-negative MRA result was obtained. The MRA-derived level of the feeding artery in S-DAVF agreed with DSA in 14 of 19 cases. In 5 cases, a mis-match of 1 vertebral level (not side) was noted for the feeding artery. For the tentorial AVF, only the spinal drainage was depicted; the feeding artery was outside the MRA field of view. In intra-dural SAVM, the main feeding artery was identified by MRA in 10 of 11 patients. Magnetic resonance angiography could differentiate between glomerular and fistulous SAVM in 4 of 6 cases and between sacral SDAVF and filum terminale SAVM in 2 of 5 cases. The authors concluded that MRA reliably detects or excludes various types of spinal AV abnormalities and localizes the (predominant) arterial feeder of most spinal AV shunts. Although classification of the subtype of SAVMs remains difficult, with MRA it greatly helps to focus subsequent DSA.

Sharma and Westesson (2008) noted that contrast-enhanced MRA has been increasingly used in the evaluation of spinal vascular malformations. Furthermore, in a review on advances in spinal cord MRA, Backes and Nijenhuis (2008) noted that current fast contrast-enhanced MR techniques are able to
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I. visualize vessels supplying or draining the spinal cord and

II. differentiate spinal cord arteries from veins.

The localization of the Adamkiewicz artery, the largest artery supplying the thoraco-lumbar spinal cord, has become possible in a reproducible and reliable manner. Knowledge of the anatomic location of this artery and its arterial supplier may be of benefit in the work-up for aortic aneurysm surgery to reduce incidences of ischemic injury. Spinal cord MRA is ready to become a diagnostic tool that can compete with catheter angiography for detecting and localizing arterial feeders of vascular lesions and is strongly advised for use prior to invasive catheter angiography.

An UpToDate review on "Prevalence and evaluation of ventricular premature beats" (Podrid, 2012) does not mention the use of magnetic resonance angiography.

Lookstein et al (2004) compared the findings of time resolved-MRA (TR-MRA) with conventional angiography for the characterization of endoleaks. Between June 2002 and June 2003, 12 patients with documented endoleaks following endovascular repair of aortic aneurysms (10 abdominal and 2 thoracic) underwent TR-MRA to identify and characterize the endoleak. All patients had nitinol-based aortic stent grafts. MRA was performed on a 1.5-Tesla magnet (Sonata class; Siemens Medical Systems, Iselin, NJ). The TR-MRA studies were reviewed under continuous observation as a "cine MR angiogram". These MRA data sets were used to classify the endoleaks into types 1 through 3. The patients underwent conventional angiography following the MRA to confirm the findings and to plan treatment. The MRA findings were compared with the findings made at conventional arteriography. TR-MRA identified 7 patients with type 1 leaks, including 4 proximal and 3 distal. Four patients had type 2 leaks, including 2 arising from the inferior mesenteric artery and 2 from an ilio-lumbar artery. One patient had a type 3 leak. Conventional angiography confirmed the type of endoleak in all 12 patients. The authors concluded that these initial results demonstrated TR-MRA to be an effective non-invasive method for classifying endoleaks. This technique may allow for screening of patients with endoleaks to identify those requiring urgent repair.

The American College of Radiology (ACR)/North American Society for Cardiovascular Imaging (NASCI)/Society for Pediatric Radiology (SPR)'s practice guideline on “The performance of pediatric and adult body magnetic resonance angiography (MRA)” (ACR-NASCI-SPR, 2010) stated that abdominal and pelvic MRA can be used for post-procedure assessment for detection of suspected leak following aortic aneurysm surgery or MR-compatible aortic stent graft placement”. Moreover, the ACR’s Appropriateness Criteria on “Abdominal Aortic Aneurysm: Interventional Planning and Follow-up” (2012) stated that “For detection and sizing of endoleak, MRA is at least as sensitive as, and probably better than CTA …. 3D contrast-enhanced MRA and time resolved MRA are highly sensitive to endoleaks”. The ACR's recommendation was given a “7” rating; and 7, 8, and 9 “ratings" denote "Usually appropriate”.

Furthermore, an UpToDate review on “Endovascular repair of abdominal aortic aneurysm” (Chaer, 2014) states that “CT angiography with delayed images is the most widely used modality for follow-up after endovascular aneurysm repair (EVAR). It is accurate for maximal diameter measurement, and for the detection of endoleak and other device-related complications. However, CT angiography is costly and repeated radiation exposure is associated with an increased lifetime cancer risk. Repeated administration of intravenous contrast may also contribute to a progressive decline in renal function that has been observed following EVAR. The guidelines for the management of abdominal aortic aneurysm (AAA) from the Society for Vascular Surgery advocate CT angiography at 1 and 12 months during the first year after EVAR. Imaging at six months is no longer routinely recommended unless an endoleak or other device-related abnormality is identified at the one-month imaging study after EVAR. If an endoleak or aneurysm enlargement is not documented during the first year after EVAR, DU [duplex ultrasonography] is an alternative to CT angiography for ongoing postoperative surveillance …. MR imaging is not a standard modality for EVAR surveillance, but can be used in specific situations where CT angiography is contraindicated. The advantage of MR imaging is the lack of exposure to ionizing radiation. Disadvantages are its lack of wide availability and difficulty evaluating device
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integrity due to artifact. The placement of stent-grafts made of nitinol does not preclude MR imaging, though MR imaging is contraindicated for stainless-steel-based grafts (e.g., Cook, Zenith)".

Miller et al (2009) stated that neuro-vascular compression (NVC) of the trigeminal nerve is associated with trigeminal neuralgia (TN), but also occurs in many patients without facial pain. These researchers identified anatomical characteristics of NVC associated with TN. A total of 30 patients with type 1 TN (intermittent shock-like pain) and 15 patients without facial pain underwent imaging for analysis of 30 trigeminal nerves ipsilateral to TN symptoms, 30 contralateral to TN symptoms, and 30 in asymptomatic patients were include in this study. Patients underwent 3-T MRI including balanced fast-field echo and MRA. Images were fused and reconstructed into virtual cisternoscopy images that were evaluated to determine the presence and degree of NVC. Reconstructed coronal images were used to measure nerve diameter and cross-sectional area. The incidence of arterial NVC in asymptomatic nerves, nerves contralateral to TN symptoms, and nerves ipsilateral to TN symptoms was 17 %, 43 %, and 57 %, respectively. The difference between symptomatic and asymptomatic nerves was significant regarding the presence of NVC, nerve distortion, and the site of compression (p < 0.001, Fisher exact test). The most significant predictors of TN were compression of the proximal nerve (odds ratio 10.4) and nerve indentation or displacement (odds ratio 4.3). There was a tendency for the development of increasingly severe nerve compression with more advanced patient age across all groups. Decreased nerve size was observed in patients with TN but did not correlate with the presence or extent of NVC. The authors concluded that trigeminal NVC occurs in asymptomatic patients but is more severe and more proximal in patients with TN. Moreover, they stated that this information may help identify patients who are likely to benefit from micro-vascular decompression (MVD).

Zacest et al (2010) stated that TN is a neuropathic pain syndrome that is often associated with NVC of the TN and may be effectively treated with MVD. The authors used high-resolution MRI with 3D reconstruction in patients with constant facial pain (type 2 TN) to determine the presence/absence of NVC and thus a potential MVD benefit. They retrospectively contacted patients to evaluate outcome. All patients who reported spontaneous onset of constant facial pain (type 2 TN), which occurred at least 50 % of the time, who had undergone high-resolution 3-T MRI with 3D reconstruction were retrospectively selected for this study. Clinical history, facial pain questionnaire data, physical examination findings, and results from 3-T 3D MRI reconstruction were recorded for all patients. Intraoperative findings and clinical pain outcome were recorded for all patients who underwent MVD. Data obtained in 27 patients were assessed. On the basis of history and 3D MRI reconstruction findings, 13 patients were selected for MVD (Group A) and 14 underwent conservative treatment (Group B). Typical or suspected artery- or vein-induced NVC was predicted pre-operatively in 100 % of Group A patients and in 0 % of Group B patients. At the time of MVD, definitive NVC was confirmed in 11 (84.6 %) of 13 Group A patients. Following MVD, facial pain was completely relieved in 3 (23 %), improved in 7 (53.8 %), and no better in 3 (23 %) of 13 Group A patients. A history of episodic (type 1 TN) pain at any time was reported in 100 % and 50 % of Group A and Group B patients, respectively. A type 1 TN pain component was reportedly improved/relieved in all Group A patients, but the type 2 TN pain component was improved in only 7 (53.8 %) of 13 patients. The mean post-operative follow-up duration was 13 months. The authors concluded that high-resolution 3D MRI reconstruction in patients with constant facial pain (type 2 TN) can help determine the presence/absence of NVC. They stated that surgical selection based on both clinical and radiological criteria has the potential to improve surgical outcome in patients with type 2 TN who may potentially benefit from MVD. However, even in such selected patients, pain relief is likely to be incomplete.

Leal et al (2014) prospectively evaluated atrophic changes in trigeminal nerves (TGNs) using measurements of volume (V) and cross-sectional area (CSA) from high-resolution 3-T MR images obtained in patients with unilateral TN, and correlated these data with patient and NVC characteristics and with clinical outcomes. Anatomical TGN parameters (V and CSA) were obtained in 50 patients (30 women and 20 men; mean age of 56.42 years, range of 22 to 79 years) with classic TN before treatment with MVD. Parameters were compared between the symptomatic (ipsilateralTN) and
asymptomatic (contralateral TN) sides of the face; 20 normal control subjects were also included. Two independent observers blinded to the side of pain separately analyzed the images. Measurements of V (from the pons to the entrance of the nerve into Meckel's cave) and CSA (at 5 mm from the entry of the TGN into the pons) for each TGN were performed using imaging software and axial and coronal projections, respectively. These data were correlated with patient characteristics (age, duration of symptoms before MVD, side of pain, sex, and area of pain distribution), NVC characteristics (type of vessel involved in NVC, location of compression along the nerve, site of compression around the circumference of the root, and degree of compression), and clinical outcomes at the 2-year follow-up after surgery. Comparisons were made using Bonferroni's test. Inter-observer variability was assessed using the Pearson correlation coefficient. The mean V of the TGN on the ipsilateral TN (60.35 ± 21.74 mm³) was significantly smaller (p < 0.05) than those for the contralateral TN and controls (78.62 ± 24.62 mm³ and 89.09 ± 14.72 mm³, respectively). The mean CSA of the TGN on the ipsilateral TN (4.17 ± 1.74 mm²) was significantly smaller than those for the contralateral TN and controls (5.41 ± 1.89 mm² and 5.64 ± 0.85 mm², respectively). The ipsilateral TN with NVC Grade III (marked indentation) had a significantly smaller mean V than the ipsilateral TN with NVC Grade I (mere contact), although it was not significantly smaller than that of the ipsilateral TN with NVC Grade II (displacement or distortion of root). The ipsilateral TN with NVC Grade III had a significantly smaller mean CSA than the ipsilateral TN with NVC Grades I and II (p < 0.05). The TGN on the ipsilateral TN in cured patients had a smaller mean CSA than that on the ipsilateral TN of patients with partial pain relief or treatment failure (p < 0.05). The same finding was almost found in relation to measurements of V, but the p value was slightly higher at 0.05. The authors concluded that the findings of this study showed that TGN atrophy in patients with TN can be demonstrated by high-resolution imaging. Moreover, they stated that these data suggested that atrophic changes in TGNs, which significantly correlated with the severity of compression and clinical outcomes, may help to predict long-term prognosis after vascular decompression.

An UpToDate review on “Trigeminal neuralgia” (Bajwa et al, 2014) states that “Neuroimaging with head CT or MRI is useful for identifying the small proportion of patients who have a structural lesion (e.g., tumor in the cerebellopontine angle, demyelinating lesions including multiple sclerosis) as the cause of painful trigeminal neuropathy. In addition, high resolution MRI and magnetic resonance angiography (MRA) may be useful for identifying vascular compression as the etiology of classic TN, but the utility of these studies has not been established .... The 2008 AAN/EFNS practice parameter identified seven studies that performed high-resolution brain MRI and/or magnetic resonance angiography (MRA) to demonstrate neurovascular compression in patients with TN. The following observations were made:

- There was wide variation among the included studies for both sensitivity (range 52 to 100 %) and specificity (29 to 93 %).
- In 3 of the 5 highest-quality MRI studies (cohort surveys with prospective data collection), the difference in rate of neurovascular trigeminal nerve compression on the symptomatic side compared with asymptomatic side was statistically non-significant.

Given these inconsistent results, the AAN/EFNS concluded that there is insufficient evidence to support or refute the utility of MRI to identify neurovascular compression in classic TN, or to indicate the most reliable MRI technique”.

**Magnetic Resonance Angiography (MRA) for the Diagnosis of Cerebral Arteriovenous Malformation:**

In a retrospective, observational study, Chowdhury et al (2015) compared MRA and DSA in diagnosis of cerebral arterio-venous malformation (AVM). A total of 30 patients with hemorrhagic stroke age ranging from 13 to 65 years were selected on the basis of inclusion and exclusion criteria as the study sample. MRA and DSA were done in all the selected patients. The mean age of the patients of hemorrhagic stroke was 30.3 ± 14.3 years and male to female ratio was 2.7:1. Regarding the venous drainage of AVM 13 and 12 were superficial and deep, respectively, and evaluated 100 % by MRA. In the diagnosis of cerebral AVM nidus size S1: less than 3 and S2: 3 to 6 cm sensitivity was 100 % but
Magnetic Resonance Angiography (MRA) and Magnetic Resonance Venography (MRV) accuracy was 100 % and 73.3 %, respectively. DSA was 100 % sensitive in the diagnosis of superficial and deep venous drainage AVM. Regarding the eloquence of brain area 15 had no eloquence by both MRA and DSA and identification of eloquence of brain area sensitivity was 73.3 % and accuracy was 86.7 %. The main feeding vessels were found (22, 73.3 %) in both DSA and MRA findings. Distal vessels was seen (8, 26.7 %) in DSA but not seen in MRA findings. Intra-nidal aneurysm and angiopathic AVM were seen in 3 (10.0 %) and 4 (13.3 %), respectively in DSA. This study was carried out to diagnose the patients presented with cerebral AVM by MRA and DSA. The authors concluded that MRA could not be evaluated flow status of AVM, distal feeding arteries, intra-nidal aneurysm and angiopathic AVM, which could be detected by DSA. So, DSA is superior to MRA in diagnosis of cerebral AVM.

MRA for the Diagnosis and Treatment Response in Individuals with Moyamoya Disease:

Uchino et al (2015) stated that noncontrast-enhanced time-resolved 4-dimensional MRA using an arterial spin labeling technique (ASL-4D MRA) is emerging as a next generation angiography for the management of neurovascular diseases. This study evaluated the feasibility of ASL-4D MRA for the diagnosis of Moyamoya disease (MMD) and MMD staging by using DSA and TOF MRA as current standards. A total of 11 consecutive non-operated patients who underwent DSA for the diagnosis of MMD were recruited. Two independent observers evaluated the 3 tests. The data were analyzed for inter-observer and inter-modality agreements on MMD stage; 9 of 22 hemispheres underwent surgical re-vascularization and ASL-4D MRA was repeated post-operatively. Time-resolved inflow of blood through the cerebral vessels, including moyamoya vessels, was visualized in all the 22 non-operated hemispheres. MMD stages assessed by DSA and ASL-4D MRA were completely matched in 18 hemispheres, with a significant positive correlation between these modalities (r = 0.93, p < 0.001). Inter-observer agreement with ASL-4D MRA (κ = 0.91 ± 0.04, p < 0.001) and inter-modality agreement between ASL-4D MRA and DSA (κ = 0.93 ± 0.04, p < 0.001) were both excellent. MMD stages assessed by ASL-4D MRA have also a significant positive correlation with those assessed by TOF MRA (r = 0.68, p = 0.004). Repeated ASL-4D MRA clearly demonstrated the bypassed arteries and changes in the dynamic flow patterns of cerebral arteries in all the 9 hemispheres after surgical re-vascularization. Of these, post-operative focal hyper-perfusion was detected by single photon emission tomography in 7 hemispheres. In 5 of the 7 hemispheres (71 %) with post-operative hyper-perfusion, ASL-4D MRA demonstrated focal hyper-intense signals in the bypassed arteries, although TOF MRA did not. The authors concluded that noninvasive ASL-4D MRA is feasible for the diagnosis of MMD staging. This next generation angiography may be useful for monitoring disease evolution and treatment response in cerebral arteries after revascularization surgery in MMD. These preliminary findings need to be validated by well-designed studies.

MRA for the Evaluation of Aneurysm Coiling:

In a systematic review and meta-analysis, Ernst et al (2015) examined the inter-rater reliability of visual rating of aneurysm occlusion as study end-point. Electronic databases (MEDLINE, EMBASE, PubMed, and the Cochrane Library) were searched up to June 2014. Assessment of risk for bias was based on the Quality Appraisal Tool for Studies of Diagnostic Reliability and the Guidelines for Reporting Reliability and Agreement studies. Inter-rater reliability estimates were pooled across studies using meta-analysis, and the influence of several factors (e.g., imaging methods, grading scales, and occlusion rate) was tested with meta-regression. From 1,193 titles, 644 abstracts and 87 full-text versions were reviewed. A total of 26 articles met the inclusion criteria and provided 77 reliability estimates; 21 different rating scales were used, and statistical analysis varied. Mean inter-rater agreement of the pooled studies was substantial (κ = 0.65; 95 % confidence interval [CI]: 0.60 to 0.69). Reliability varied significantly as a function of imaging methods, grading scales, occlusion rates, and their interaction. Observer agreement substantially increased with increasing occlusion rate in digital subtraction angiography but not in MA. Reliability was higher in studies using 2- or 3-value grading scales than in studies with 4-value grading scales. The authors concluded that there was
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significant heterogeneity between studies evaluating the reliability of visual evaluation of aneurysm coiling. On the basis of this analysis, these researchers found that the combination of MRA, 3-value grading scale, and 2 trained raters appeared most promising for usage as surrogate study end-points.

MRA for the Evaluation of Varices at Hepatico-Jejunostomy after Liver Transplantation:

Jimbo et al (2015) reported the case of a 7-year old Japanese girl who had undergone living-donor liver transplantation (LT) at the age of 10 months for decompensated liver cirrhosis caused by biliary atresia presented with recurrent episodes of obscure gastrointestinal bleeding (GIB) with anemia. Over the following 6 years, she experienced 5 episodes of GIB requiring hospitalization. Subsequent evaluations including repeat esophagastroduodenoscopy (EGD), colonoscopy (CS), contrast-enhanced computed tomography (CT), and Meckel's scan all failed to reveal a bleeding source. However, varices at the site of hepatico-jejunostomy were detected on abdominal ultrasonography and MRA at the age of 7 years. The authors concluded that MRA might be more helpful than contrast-enhanced CT for identifying such bleeding. These preliminary findings need to be validated by well-designed studies.

MRA for the Surveillance of Individuals with Brain Cancer Following Radiotherapy:

In a feasibility study, Bullitt et al (2007) examined if MRA can depict intracranial vascular morphologic changes during treatment of brain metastases from breast cancer and if serial quantitative vessel tortuosity measurements can be used to predict tumor treatment response sooner than traditional methods. Institutional review board approval and informed consent were obtained for this HIPAA-compliant study. A total of 22 women aged 31 to 61 years underwent brain MRA prior to and 2 months after initiation of lapatinib therapy for brain metastases from breast cancer. Vessels were extracted from MR angiograms with a computer program. Changes in vessel number, radius, and tortuosity were calculated mathematically, normalized with values obtained in 34 healthy control subjects (19 women, 15 men; age range of 19 to 72 years), and compared with subsequent assessments of tumor volume and clinical course. All patients exhibited abnormal vessel tortuosity at baseline. Nineteen (86 %) patients did not exhibit improvement in vessel tortuosity at 2-month follow-up, and all patients demonstrated tumor growth at 4-month follow-up. Vessel tortuosity measurements enabled these researchers to correctly predict treatment failure 1 to 2 months earlier than did traditional methods. Three (14 %) patients had quantitative improvement in vessel tortuosity at 2-month follow-up, with drop-out of small abnormal vessels and straightening of large vessels. Each of the 2 patients for whom further follow-up data were available responded to treatment for more than 6 months. The authors concluded that these findings established the feasibility of using MRA to quantify vessel shape changes during therapy. Moreover, they stated that although further research is required, results suggested that changes in vessel tortuosity might enable early prediction of tumor treatment response.

An Information Sheet on “Further tests for brain tumours” from Cancer Research UK (Last updated November 25, 2013) did not mention annual MRA as a surveillance tool for patients with brain cancer.

A “Brain Tumor Glossary of Terms” from the Brain Tumor Trial Collaborative (2015) states that “MRA does not have significant application for the detection or definition of cancer of the brain”.

Also, an UpToDate review on “Assessment of disease status and surveillance after treatment in patients with brain tumors” (Wen, 2015) does not mention MRA as a management tool.

Furthermore, National Comprehensive Cancer Network (NCCN)’s clinical practice guideline on “Central nervous system cancers” (Version 1.2015) states that “Cerebral angiography is occasionally performed, often for surgical planning ….”; it does not mention MRA as a management tool.

The use of an MRA/MRV as part of the work-up of a patient with suspected cerebral thrombosis (i.e., dural sagittal or cavernous sinus thrombosis) must be considered on a case by case basis. Magnetic resonance imaging is considered the imaging method of choice for establishing the diagnosis, but
MRA/MRV may be useful in following the course of the disease.

Magnetic resonance venography (MRV) is now very effective for the evaluation of diseases of larger veins. The specific indications for using MRV for evaluating the vena cavae are diagnosis of vena caval thrombus, differentiation of tumor thrombus and blood clot of the vena cava, diagnosis of superior vena caval syndrome, identification of superior vena caval invasion or encasement by lung or mediastinal tumors, diagnosis of the Budd-Chiari syndrome, diagnosis of caval anomalies such as persistent left superior vena cava and interrupted inferior vena cava, and identification of the presence and cause of obstruction or occlusion of the brachiocephalic, subclavian, and jugular veins.

Duplex ultrasonography is the typical initial diagnostic test for deep vein thrombosis (DVT). Magnetic resonance venography has not been shown to be superior to ultrasonography, except in imaging the deep femoral and hypogastric vessels. However, information about these vessels is frequently not needed to make patient management decisions, except perhaps in patients with pulmonary emboli where the source of the emboli has not been identified by ultrasonography. McRae and Ginsberg (2004) MRV has the potential to be used as a stand-alone test for DVT but requires further evaluation. Moreover, in a retrospective study (n = 973), Borer et al (2005) found that discontinuation of screening by means of ultrasound and MRV for the diagnosis of DVT did not change the rate of pulmonary embolism in patients with closed fractures of the pelvis or acetabulum.

Bates et al (2012) stated that objective testing for DVT is crucial because clinical assessment alone is unreliable and the consequences of misdiagnosis are serious. This guideline focused on the identification of optimal strategies for the diagnosis of DVT in ambulatory adults. The methods of this guideline followed those described in Methodology for the Development of Antithrombotic Therapy and Prevention of Thrombosis Guidelines: Antithrombotic Therapy and Prevention of Thrombosis, 9th ed: American College of Chest Physicians Evidence-Based Clinical Practice Guidelines. These investigators suggested that clinical assessment of pre-test probability of DVT, rather than performing the same tests in all patients, should guide the diagnostic process for a first lower extremity DVT (Grade 2B). In patients with a low pre-test probability of first lower extremity DVT, these researchers recommended initial testing with D-dimer or ultrasound (US) of the proximal veins over no diagnostic testing (Grade 1B), venography (Grade 1B), or whole-leg US (Grade 2B). In patients with moderate pre-test probability, they recommended initial testing with a highly sensitive D-dimer, proximal compression US, or whole-leg US rather than no testing (Grade 1B) or venography (Grade 1B). In patients with a high pre-test probability, they recommended proximal compression or whole-leg US over no testing (Grade 1B) or venography (Grade 1B). The authors concluded that favored strategies for diagnosis of first DVT combined use of pre-test probability assessment, D-dimer, and US. There is lower-quality evidence available to guide diagnosis of recurrent DVT, upper extremity DVT, and DVT during pregnancy.

The role of chronic cerebrospinal venous insufficiency (CCSVI) in the pathogenesis of multiple sclerosis (MS) is a matter of debate. Chronic cerebrospinal venous insufficiency was first diagnosed using specialized trans-cranial and extra-cranial Doppler ultrasonography. Some have advocated the use of MRV in place of trans-cranial Doppler because the results of MRV are less operator dependent. However, there are limited data to support the use of MRV in diagnosis of CCSVI. In a pilot study, Hojnacki et al (2010) the value of neck MRV for the diagnosis of CCSVI compared to Doppler sonography (DS) and selective venography (SV) in patients with MS and in healthy controls (HC). A total of 10 MS patients and 7 HC underwent DS, 2D-Time-Of-Flight (TOF) venography and 3D-Time Resolved Imaging of Contrast Kinetics angiography (TRICKS). Patients with MS also underwent SV. The internal jugular veins (IJVs) and the vertebral veins (VVs) were assessed by both MRV sequences, and the findings were validated against SV and DS; SV has been considered the diagnostic gold standard for MS patients. All MS patients and none of the HC presented CCSVI, according to the DS criteria. This was confirmed by SV. For CCSVI diagnosis, DS showed sensitivity, specificity, accuracy, positive-predictive value (PPV) and negative-predictive value (NPV) of 100 %, whereas the figures were 40 %, 85 %, 58 %, 80 % and 50 % for 3D-TRICKS, and 30 %, 85 %, 52 %, 75 % and 46 % for 2D-TOF in the IJVs. In MS patients, compared to SV, DS showed sensitivity,
specificity, accuracy, PPV and NPV of 100 %, 75 %, 95 %, 94 % and 100 %, whereas the figures were 31 %, 100 %, 45 %, 100 % and 26 % for 3D-TRICKS and 25 %, 100 %, 40 %, 100 % and 25 % for 2D-TOF in the IJVs. The authors concluded that the use of MRV for diagnosis of CCSVI in MS patients has limited value, and the findings should be interpreted with caution and confirmed by other imaging techniques such as DS and SV.

Abdalla et al (2015) searched the literature for further evidence for the use of MRV in the detection of suspected DVT and re-evaluated the accuracy of MRV in the detection of suspected DVT. PubMed, EMBASE, Scopus, Cochrane, and Web of Science were searched. Study quality and the risk of bias were evaluated using the QUADAS 2. A random effects meta-analysis including subgroup and sensitivity analyses were performed. The search resulted in 23 observational studies all from academic centers; 16 articles were included in the meta-analysis. The summary estimates for MRV as a diagnostic non-invasive tool revealed a sensitivity of 93 % (95 % CI: 89 % to 95 %) and specificity of 96 % (95 % CI: 94 % to 97 %). The heterogeneity of the studies was high. Inconsistency (I²) for sensitivity and specificity was 80.7 % and 77.9 %, respectively. The authors concluded that further studies investigating the use of MRV in the detection of suspected DVT did not offer further evidence to support the replacement of US with MRV as the first-line investigation. However, they stated that MRV may offer an alternative tool in the detection/diagnosis of DVT for whom US is inadequate or not feasible (such as in the obese patient).

Pelvic Resonance Venography (MRV) for the Diagnostic Evaluation of Cryptogenic Stroke:

Liberman et al (2014) stated that paradoxical embolization is frequently posited as a mechanism of ischemic stroke in patients with patent foramen ovale (PFO). Several studies have suggested that the deep lower extremity (LE) and pelvic veins might be an embolic source in cryptogenic stroke (CS) patients with PFO. In this single-center, retrospective, observational study, consecutive adult patients with ischemic stroke or transient ischemic attack (TIA) and a PFO who underwent pelvic MRV as part of an inpatient diagnostic evaluation were included in this study to determine pelvic and LE DVT prevalence in CS versus non-CS stroke subtypes. Among the 131 patients who met inclusion criteria, 126 (96.2 %) also had LE duplex US data. DVT prevalence overall was 7.6 % (95 % CI: 4.1 to 13.6), pelvic DVT 1.5 % (95 % CI: 0.1 to 5.8), and LE DVT 7.1 % (95 % CI: 3.6 to 13.2). One patient with a pelvic DVT also had a LE DVT. Comparing patients with CS (n = 98) with non-CS subtypes (n = 33), there was no significant difference in the prevalence of pelvic DVT (2.1 % versus 0 %, p = 1), LE DVT (6.2 % versus 10.3 %, p = 0.43), or any DVT (7.2 % versus 9.1 %, p = 0.71). The authors concluded that among patients with ischemic stroke/TIA and PFO, the majority of detected DVTs were in LE veins rather than the pelvic veins and did not differ by stroke subtype. They stated that the routine inclusion of pelvic MRV in the diagnostic evaluation of CS warrants further prospective investigation.

Osgood et al (2015) noted that substantial proportion of ischemic strokes has no identified underlying cause. Notably, the prevalence of a PFO is increased in CS populations, which may serve as a conduit for paradoxical emboli originating from DVT including the pelvic veins. Yet, there are no published guidelines for the assessment of pelvic veins as part of the stroke work-up and few studies have systematically investigated pelvic veins as a potential source for paradoxical emboli in CS patients. Further, there is a relative paucity of data regarding pelvic DVT in CS and results have been conflicting. These investigators determined the prevalence of pelvic DVT in select CS patients with PFO who underwent MRV. They retrospectively identified patients (n = 50) who underwent contrast-enhanced pelvic MRV at the discretion of the treating physician for the evaluation of CS in the presence of a PFO during hospitalization at a single academic stroke center between January 2011 through December 2013. Multivariable logistic regression analyses were used to assess for factors independently associated with the presence of an abnormal MRV pelvis. Patients (47 ± 13 years of age) had MRV performed 4 ± 3 days after their incident stroke; 9 patients had an abnormal MRV (18 %). Of these, 4 (8 %) had pelvic vein thrombosis and 5 (10 %) a May-Thurner anatomic variant. All patients with pelvic DVT were subsequently anti-coagulated with warfarin (none had abnormal hypercoagulability testing). Clinical clues suggesting paradoxical embolism were present in as many
Magnetic Resonance Angiography (MRA) and Magnetic Resonance Venography (MRV) were used to diagnose pelvic vein pathology in 40% of patients. On multivariable logistic regression, a history of any risk factors predisposing to DVT (odds ratios [OR] 6.7; coefficient 1.9; BCa 95% CI: 0.08 to 20.2; p = 0.014) as well as the number of predisposing risk factors (OR 3.9; coefficient 1.4; BCa 95% CI: 0.25-4.2; p = 0.005) predicted the presence of pelvic vein pathology on MRV. The authors demonstrated a relatively high prevalence of pelvic DVT among select CS patients emphasizing the importance of considering the pelvic veins as a potential source for emboli particularly in the presence of risk factors known to predispose DVT. Because patients were included at the treating physician’s discretion, these findings reflected “real-life” practice. They stated that the results may be of clinical importance as inclusion of pelvic vein imaging in CS patients with PFO had impactful therapeutic and nosologic implications. These researchers noted that further study is needed to define patients most likely to benefit from pelvic vein imaging.

**MRV for Screening Venous Thromboembolism Following Musculoskeletal Trauma:**

On behalf of the Orthopaedic Trauma Association Evidence Based Quality Value and Safety Committee, Sagi and colleagues (2015) provided a summation of the current practice patterns of North American orthopedic surgeons for venous thrombo-embolism (VTE) prophylaxis after musculoskeletal trauma, and established a set of guidelines and recommendations based on the most current and best available evidence for VTE prophylaxis after musculoskeletal trauma.

A 24 item questionnaire titled "OTA VTE Prophylaxis Survey" was sent to active members of the Orthopedic Trauma Association. PubMed and OVID/MEDLINE were used to search the current published literature regarding VTE prophylaxis in trauma patients using the following search terms: deep venous thrombosis, DVT, pulmonary embolism, PE, venous thromboembolism, VTE, prophylaxis, trauma, fracture, pneumatic compression device, PCD, sequential compression device, SCD, screening, ultrasound, duplex, ultrasonography, DUS, venography, magnetic resonance venography, MRV, inferior vena cava, IVC, filter, and IVCF. Each recommendation was graded using articles that were considered by the subcommittee as "the best available evidence" using the grading system adopted and endorsed by the American Academy of Orthopedic Surgeons’ Evidenced Based Quality and Value committee. Overall, 185 of 1,545 members completed the online survey. The range and variety of prophylaxis and screening methods used among orthopedic trauma surgeons in North America is large, with a number of agents or methods for which no literature exists to support their use in musculoskeletal trauma. A set of recommendations and guidelines were constructed based on the results of the literature analysis and graded according to guidelines mentioned above. The authors concluded that due to the wide variability in practice patterns, poor scientific support for various therapeutic regimens and important medical-legal implications highlighted by the survey, a standardized set of guidelines and recommendations for VTE prophylaxis after musculoskeletal trauma will be critical in helping to improve patient care and minimize surgeons' exposure to potentially litigious activity.

**Quantitative MRV for Measurement of Venous Flow after Cerebral Venous Sinus Stenting:**

Esfahani et al (2015) stated that endovascular stenting is an effective treatment for patients with clinically significant cerebral venous sinus stenosis. Traditionally, stenting is indicated in elevated intravenous pressures on conventional venography; however, non-invasive monitoring is more desirable. Quantitative MRV (qMRV) is an imaging modality that measures blood flow non-invasively. Established in the arterial system, applications to the venous sinuses have been limited. These researchers examined qMRV in the measurement of venous sinus flow in patients undergoing endovascular stenting and identified a relationship with intravenous pressures. A total of 5 patients with intra-cranial hypertension secondary to venous sinus stenosis underwent cerebral venous stenting between 2009 and 2013 at a single institution. Pre-operatively, venous sinus flow was determined by using qMRV, and intravenous pressure was measured during venography. After stenting, intravenous pressure, qMRV flow, and clinical outcomes were assessed and compared. A mean pre-stenotic...
intravenous pressure of 45.2 mm Hg was recorded before stenting, which decreased to 27.4 mm Hg afterward (Wilcoxon signed rank test p = 0.04). Total jugular outflow on qMRV increased by 260.2 ml/min. Analysis of the change in intravenous pressure and qMRV flow identified a linear relationship (Pearson correlation r = 0.926). All patients displayed visual improvement at 6 weeks. The authors concluded that venous outflow by qMRV increased after endovascular stenting and correlated with significantly improved intravenous pressures. They stated that these findings introduced qMRV as a potential adjunct to measure venous flow after stenting, and as a plausible tool in the selection and post-operative surveillance of the patient who has cerebral venous sinus stenosis.

**MRA for Evaluation of Vasa Previa:**

Iwahashi and associates (2016) noted that vasa previa is a rare complication, and rupture of vasa previa during pregnancy may lead to significant perinatal mortality. These investigators reported a case of vasa previa evaluated prenatally using non-contrast time-of-flight MRA (TOF-MRA). A 22-year old primiparous woman was referred to the authors’ hospital due to suspicion of vasa previa. Transvaginal US showed 2 vessels running over the internal os. To obtain further information, MRI and TOF-MRA were performed. Caesarean section was performed, and macroscopic findings of the vascular distribution on the fetal membrane were consistent with those identified by TOF-MRA. The authors concluded that TOF-MRA in addition to MRI may be an option for prenatal identification of the precise 3D vascular distribution in patients with vasa previa. The role of MRA for evaluation of patients with vasa previa needs to be further investigated.

**Ferumoxytol-Enhanced MRA for Evaluation of Transplant Renal Artery Stenosis:**

Fananapazir and co-workers (2016) determined the accuracy of ferumoxytol-enhanced MRA in assessing the severity of transplant renal artery stenosis (TRAS), using digital subtraction angiography (DSA) as the reference standard. The authors’ Institutional Review Board approved this retrospective, Health Insurance Portability and Accountability Act-compliant study. A total of 33 patients with documented clinical suspicion for TRAS (elevated serum creatinine, refractory hypertension, edema, and/or audible bruit) and/or concerning sonographic findings (elevated renal artery velocity and/or intra-parenchymal parvus tardus waveforms) underwent a 1.5T MRA with ferumoxytol prior to DSA. All DSAs were independently reviewed by an interventional radiologist and served as the reference standard. The MRAs were reviewed by 3 readers who were blinded to the US and DSA findings for the presence and severity of TRAS. Sensitivity, specificity, and accuracy for identifying substantial stenoses (greater than 50 %) were determined. Intra-class correlation coefficients (ICCs) were calculated among readers. Mean differences between the percent stenosis from each MRA reader and DSA were calculated. On DSA, a total of 42 stenoses were identified in the 33 patients. The sensitivity, specificity, and accuracy of MRA in detecting substantial stenoses were 100 %, 75 to 87.5 %, and 95.2 to 97.6 %, respectively, among the readers. There was excellent agreement among readers as to the percent stenosis (ICC = 0.82); MRA over-estimated the degree of stenosis by 3.9 to 9.6 % compared to DSA. The authors concluded that ferumoxytol-enhanced MRA provided high sensitivity, specificity, and accuracy for determining the severity of TRAS. They stated that these findings suggested that ferumoxytol-enhanced MRA can potentially be used as a non-invasive examination following US to reduce the number of unnecessary conventional angiograms. These preliminary findings need to be validated by well-designed studies.

**MRA for Prediction of Pulmonary Hypertension:**

Rengier and colleagues (2016) demonstrated the feasibility of automated 3D volumetry of central pulmonary arteries based on MRA to evaluate pulmonary artery volumes in patients with pulmonary hypertension compared to healthy controls, and examined the potential of the technique for predicting pulmonary hypertension. Magnetic resonance angiography of pulmonary arteries was acquired at 1.5T in 20 patients with pulmonary arterial hypertension and 21 healthy normotensive controls; 3D model-based image analysis software was used for automated segmentation of main, right and left pulmonary arteries (MPA, RPA and LPA). Volumes indexed to vessel length and mean, minimum and maximum
Magnetic Resonance Angiography (MRA) and Magnetic Resonance Venography (MRV)

...diameters along the entire vessel course were assessed and corrected for body surface area (BSA). For comparison, diameters were also manually measured on axial reconstructions and double oblique multi-planar reformations. Analyses were performed by 2 cardiovascular radiologists, and by 1 radiologist again after 6 months. Mean volumes of MPA, RPA and LPA for patients/controls were 5,508 ± 1,236/3,438 ± 749, 3,522 ± 934/1,664 ± 468 and 3,093 ± 692/1,812 ± 474 μl/(cm length x m2 BSA) (all p < 0.001). Mean, minimum and maximum diameters along the entire vessel course were also significantly increased in patients compared to controls (all p < 0.001). Intra- and inter-observer agreement were excellent for both volume and diameter measurements using 3D segmentation (ICCs 0.971 to 0.999, p < 0.001). Area under the curve for predicting pulmonary hypertension using volume was 0.998 (95 % CI: 0.990 to 1.0, p < 0.001), compared to 0.967 using manually measured MPA diameter (95 % CI: 0.910 to 1.0, p < 0.001). The authors concluded that automated MRA-based 3D volumetry of central pulmonary arteries is feasible and demonstrated significantly increased volumes and diameters in patients with pulmonary arterial hypertension compared to healthy controls. They stated that pulmonary artery volume may serve as a superior predictor for pulmonary hypertension compared to manual measurements on axial images; but verification in a larger study population is needed.

MRV for Diagnosis of Pelvic Congestion Syndrome:

Champaneria and colleagues (2016) stated that pelvic congestion syndrome (PCS) is described as chronic pelvic pain (CPP) arising from dilated and refluxing pelvic veins, although the causal relationship between pelvic vein incompetence (PVI) and CPP is not established. Non-invasive screening methods such as Doppler US and MRV are used before confirmation by venography. Percutaneous embolization has become the principal treatment for PCS, with high success rates often cited. These researchers systematically reviewed the definitions and diagnostic criteria of PCS, the association between PVI and CPP, the accuracy of various non-invasive imaging techniques and the effectiveness of embolization for PVI; and identified factors associated with successful outcome. They also surveyed clinicians and patients to assess awareness and management of PCS and gauge the enthusiasm for further research. A comprehensive search strategy encompassing various terms for pelvic congestion, pain, imaging techniques and embolization was deployed in 17 bibliographic databases, including Medline, Embase and Web of Science. There was no restriction on study design. Methodological quality was assessed using appropriate tools. Online surveys were sent to clinicians and patients. The quality and heterogeneity generally precluded meta-analysis and so results were tabulated and described narratively. These investigators identified 6 association studies, 10 studies involving US, 2 studies involving MRV, 21 case series and 1 poor-quality randomized trial of embolization. There were no consistent diagnostic criteria for PCS. These researchers found that the associations between CPP and PVI were generally fairly similar, with 3 of 5 studies with sufficient data showing statistically significant associations (OR of between 31 and 117). The prevalence of PVI ranged widely, although the majority of women with PVI had CPP. Trans-vaginal Doppler US and MRV are both useful screening methods, although the data on accuracy were limited. Early substantial relief from pain symptoms was observed in approximately 75 % of women undergoing embolization, a figure which generally increased over time and was sustained. Re-intervention rates were generally low. Transient pain was a common occurrence following foam embolization, while there was a less than 2 % risk of coil migration. Confidence in the embolization technique was reasonably high, although there was a desire to strengthen the evidence base. Even among women with CPP, fewer than 50 % had any knowledge about PCS. The authors concluded that the data supporting the diagnosis and treatment of PCS were limited and of variable methodological quality. There is some evidence to tentatively support a causative association, but it cannot be categorically stated that PVI is the cause of CPP in women with no other pathology, as the 6 most pertinent studies drew on clinically disparate populations and defined PVI inconsistently. Embolization appeared to provide symptomatic relief in the majority of women and is safe. However, the majority of included studies of embolization were relatively small case series and only the randomized controlled trial (RCT) was considered at risk of potential biases. The authors concluded that there is scope and demand for considerable further research. They stated that the question of the association of PVI and CPP requires a well-designed
and well-powered case-control study, which will also provide data to derive a diagnostic standard. An adequately powered randomized trial is essential to provide evidence on the effectiveness of embolization, but this faces methodological challenges.

**Ferumoxytol-Enhanced MRV for Diagnosis of Chronic Kidney Disease:**

Luhar and associates (2016) noted that ferumoxytol is an ultra-small superparamagnetic iron oxide (USPIO) particle that is FDA-approved for parenteral treatment of iron deficiency anemia in adults with chronic kidney disease (CKD). Because of the association between gadolinium-based contrast agents and nephrogenic systemic fibrosis in patients with severe CKD, these researchers evaluated the diagnostic role of ferumoxytol-enhanced MRV in children with CKD. A total of 20 children underwent 22 high-resolution ferumoxytol-enhanced MRV examinations at 3.0 T. High-resolution 3D contrast-enhanced imaging was performed at a minimum of 3 time-points following injection of ferumoxytol at a total dose of 4 mg/kg of body weight. Two blinded pediatric radiologists independently scored 6 named veins on ferumoxytol-enhanced MRV examinations according to a 3-point subjective score, where a score greater than or equal to 2 was considered diagnostic. Additionally, all relevant venous structures in the included field of view were analyzed for occlusive or non-occlusive thrombosis, compression and presence of collaterals. All patients underwent ferumoxytol-enhanced MRV successfully and without adverse event (AE). The overall scores of the reviewing radiologists for all venous structures were 2.7 to 2.9. In all cases, the reviewers were confident basing their diagnoses on the ferumoxytol-enhanced MRV findings. In 12 of 22 examinations, findings on follow-up imaging or invasive procedures were available to correlate with the findings on ferumoxytol-enhanced MV. There was complete concordance between the findings from follow-up imaging and invasive procedures with findings from ferumoxytol-enhanced MV. The authors concluded that ferumoxytol holds promise as a powerful alternative to gadolinium-based contrast agents for reliable, high-resolution MRV in children with CKD.

### CPT Codes / HCPCS Codes / ICD-10 Codes

*Information in the [brackets] below has been added for clarification purposes. Codes requiring a 7th character are represented by "+".*

**Magnetic Resonance Angiography (MRA) & Venography (MRV):**

**Head and neck:**

CPT codes covered if selection criteria are met:

<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>70544</td>
<td>Magnetic resonance angiography, head; without contrast material(s)</td>
</tr>
<tr>
<td>70545</td>
<td>with contrast material(s)</td>
</tr>
<tr>
<td>70546</td>
<td>without contrast material(s), followed by contrast material(s) and further sequences</td>
</tr>
<tr>
<td>70547</td>
<td>Magnetic resonance angiography, neck; without contrast material(s)</td>
</tr>
<tr>
<td>70548</td>
<td>with contrast material(s)</td>
</tr>
<tr>
<td>70549</td>
<td>without contrast material(s), followed by contrast material(s) and further sequences</td>
</tr>
</tbody>
</table>

**ICD-10 codes covered if selection criteria are met for MRA:**

<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>A52.05</td>
<td>Other cerebrovascular syphilis [intracranial aneurysm]</td>
</tr>
<tr>
<td>D43.0 - D43.9</td>
<td>Neoplasm of uncertain behavior of brain and central nervous system</td>
</tr>
<tr>
<td>Code</td>
<td>Description</td>
</tr>
<tr>
<td>--------</td>
<td>-----------------------------------------------------------------------------</td>
</tr>
<tr>
<td>G08</td>
<td>Intracranial and intraspinal phlebitis and thrombophlebitis [intracranial aneurysm]</td>
</tr>
<tr>
<td>G44.1</td>
<td>Vascular headache, not elsewhere classified [sudden explosive headache, unilateral headache]</td>
</tr>
<tr>
<td>G45.0 - G45.9</td>
<td>Transient cerebral ischemic attacks and related syndromes</td>
</tr>
<tr>
<td>H34.00 - H34.03</td>
<td>Transient retinal artery occlusion</td>
</tr>
<tr>
<td>H49.00 - H49.03</td>
<td>Third [oculomotor] nerve palsy</td>
</tr>
<tr>
<td>H53.2</td>
<td>Diplopia</td>
</tr>
<tr>
<td>H54.3</td>
<td>Unqualified visual loss, both eyes</td>
</tr>
<tr>
<td>H81.10 - H81.13</td>
<td>Benign paroxysmal vertigo</td>
</tr>
<tr>
<td>H81.41 - H81.49</td>
<td>Vertigo of central origin</td>
</tr>
<tr>
<td>H93.11 - H93.19</td>
<td>Tinnitus</td>
</tr>
<tr>
<td>I60.00 - I60.9</td>
<td>Nontraumatic subarachnoid hemorrhage</td>
</tr>
<tr>
<td>I67.0 - I67.9</td>
<td>Other cerebrovascular diseases</td>
</tr>
<tr>
<td>I71.02 - I71.03</td>
<td>Dissection of abdominal or thoracoabdominal aorta</td>
</tr>
<tr>
<td>I71.3 - I71.4</td>
<td>Abdominal aortic aneurysm, ruptured or without rupture</td>
</tr>
<tr>
<td>I71.5 - I71.6</td>
<td>Thoracoabdominal aneurysm, ruptured or without mention of rupture</td>
</tr>
<tr>
<td>I77.71</td>
<td>Dissection of carotid artery</td>
</tr>
<tr>
<td>I77.74</td>
<td>Dissection of vertebral artery</td>
</tr>
<tr>
<td>M43.6</td>
<td>Torticollis</td>
</tr>
<tr>
<td>Q28.2</td>
<td>Arteriovenous malformation of cerebral vessels [not covered for magnetic resonance angiography for diagnosis]</td>
</tr>
<tr>
<td>R13.10 - R13.19</td>
<td>Dysphagia</td>
</tr>
<tr>
<td>R42</td>
<td>Dizziness and giddiness</td>
</tr>
<tr>
<td>R43.0 - R43.9</td>
<td>Disturbances of smell and taste</td>
</tr>
<tr>
<td>R47.02 - R47.9</td>
<td>Speech disturbances, not elsewhere classified</td>
</tr>
<tr>
<td>R51</td>
<td>Headache [sudden explosive headache, unilateral headache]</td>
</tr>
<tr>
<td>R55</td>
<td>Syncope and collapse</td>
</tr>
<tr>
<td>R83.9</td>
<td>Unspecified abnormal findings in cerebrospinal fluid [blood in CSF]</td>
</tr>
<tr>
<td>S15.001+ - S15.099+</td>
<td>Injury of carotid artery of neck</td>
</tr>
<tr>
<td>Z82.3</td>
<td>Family history of stroke</td>
</tr>
</tbody>
</table>
### ICD-10 codes not covered for indications listed in the CPB for MRA:

<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>C71.0 - C71.9</td>
<td>Malignant neoplasm of brain</td>
</tr>
<tr>
<td>C76.0</td>
<td>Malignant neoplasm of head, face and neck</td>
</tr>
<tr>
<td>C79.31</td>
<td>Secondary malignant neoplasm of brain</td>
</tr>
<tr>
<td>D33.0 - D33.2</td>
<td>Benign neoplasm of brain</td>
</tr>
<tr>
<td>G50.0</td>
<td>Trigeminal neuralgia [not covered for the evaluation of microvascular compression]</td>
</tr>
<tr>
<td>T86.49</td>
<td>Other complications of liver transplant [varices at hepatico-jejunostomy]</td>
</tr>
</tbody>
</table>

### ICD-10 codes covered if selection criteria are met for MRV:

<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>C71.0 - C71.9</td>
<td>Malignant neoplasm of brain</td>
</tr>
<tr>
<td>C76.0</td>
<td>Malignant neoplasm of head and neck</td>
</tr>
<tr>
<td>D33.0 - D33.2</td>
<td>Benign neoplasm of brain</td>
</tr>
<tr>
<td>D43.0 - D43.9</td>
<td>Neoplasm of uncertain behavior of brain and central nervous system</td>
</tr>
<tr>
<td>G00.0 - G03.9</td>
<td>Meningitis</td>
</tr>
<tr>
<td>G44.1</td>
<td>Vascular headache, not elsewhere classified</td>
</tr>
<tr>
<td>H47.10 - H47.13</td>
<td>Papilledema</td>
</tr>
<tr>
<td>H65.00 - H67.9</td>
<td>Otitis media</td>
</tr>
<tr>
<td>J01.00 - J01.91</td>
<td>Acute sinusitis</td>
</tr>
<tr>
<td>J32.0 - J32.9</td>
<td>Chronic sinusitis</td>
</tr>
<tr>
<td>R29.810 - R29.91</td>
<td>Other symptoms involving nervous and musculoskeletal systems [focal or sensory deficits]</td>
</tr>
<tr>
<td>R51</td>
<td>Headache</td>
</tr>
<tr>
<td>R56.00 - R56.9</td>
<td>Convulsions, not elsewhere classified [seizures]</td>
</tr>
<tr>
<td>Z79.3</td>
<td>Long-term (current) use of hormonal contraceptives</td>
</tr>
</tbody>
</table>

### ICD-10 codes not covered for indications listed in the CPB for MRV:

<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>G45.0 - G45.9</td>
<td>Transient cerebral ischemic attacks and related syndromes [diagnosis of chronic cerebro-spinal venous insufficiency]</td>
</tr>
<tr>
<td>I67.0 - I67.9</td>
<td>Other cerebrovascular diseases [diagnosis of chronic cerebro-spinal venous insufficiency]</td>
</tr>
</tbody>
</table>

### Chest:

#### CPT codes covered if selection criteria are met:

<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>71555</td>
<td>Magnetic resonance angiography, chest (excluding myocardium), with or without contrast material(s)</td>
</tr>
</tbody>
</table>
### Other CPT codes related to the CPB:

<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>75557-75564</td>
<td>Cardiac magnetic resonance imaging for velocity flow mapping</td>
</tr>
</tbody>
</table>

### HCPCS codes covered if selection criteria are met:

<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>C8909</td>
<td>Magnetic resonance angiography with contrast, chest (excluding myocardium)</td>
</tr>
<tr>
<td>C8910</td>
<td>Magnetic resonance angiography without contrast, chest (excluding myocardium)</td>
</tr>
<tr>
<td>C8911</td>
<td>Magnetic resonance angiography without contrast followed by with contrast, chest (excluding myocardium)</td>
</tr>
</tbody>
</table>

### ICD-10 codes covered if selection criteria are met for MRA:

<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>I26.01 - I26.99</td>
<td>Pulmonary embolism</td>
</tr>
<tr>
<td>I48.0 - I48.2, I48.91</td>
<td>Atrial fibrillation</td>
</tr>
<tr>
<td>I71.01</td>
<td>Dissection of thoracic aorta</td>
</tr>
<tr>
<td>I71.1</td>
<td>Thoracic aortic aneurysm, ruptured</td>
</tr>
<tr>
<td>I71.2</td>
<td>Thoracic aortic aneurysm, without rupture</td>
</tr>
<tr>
<td>Q20.0 - Q28.9</td>
<td>Congenital malformations of the circulatory system</td>
</tr>
</tbody>
</table>

### ICD-10 codes not covered for indications listed in the CPB for MRA:

<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>I49.3</td>
<td>Ventricular premature depolarization</td>
</tr>
</tbody>
</table>

### ICD-10 codes covered if selection criteria are met for MRV:

<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>I82.B11 - I82.B29</td>
<td>Embolism and thrombosis of subclavian vein</td>
</tr>
<tr>
<td>I82.210 - I82.211</td>
<td>Embolism and thrombosis of superior vena cava</td>
</tr>
<tr>
<td>I82.290</td>
<td>Acute venous embolism and thrombosis of other thoracic veins</td>
</tr>
</tbody>
</table>

### Spine:

### CPT codes covered if selection criteria are met:

<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>72159</td>
<td>Magnetic resonance angiography, spinal canal and contents, with or without contrast materials(s)</td>
</tr>
<tr>
<td>C8931</td>
<td>Magnetic resonance angiography with contrast, spinal canal and contents</td>
</tr>
<tr>
<td>C8932</td>
<td>Magnetic resonance angiography without contrast, spinal canal and contents</td>
</tr>
<tr>
<td>C8933</td>
<td>Magnetic resonance angiography without contrast followed by with contrast, spinal canal and contents</td>
</tr>
</tbody>
</table>

### ICD-10 codes covered if selection criteria are met for MRA:

<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>I77.0</td>
<td>Arteriovenous fistula, acquired [spinal cord]</td>
</tr>
<tr>
<td>Q27.9</td>
<td>Congenital malformation of peripheral vascular system, unspecified [spinal cord]</td>
</tr>
</tbody>
</table>
## Abdomen/Pelvis:

### CPT codes covered if selection criteria are met:

<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>72198</td>
<td>Magnetic resonance angiography, pelvis, with or without contrast material(s)</td>
</tr>
<tr>
<td>74185</td>
<td>Magnetic resonance angiography, abdomen, with or without contrast material(s)</td>
</tr>
</tbody>
</table>

### Other CPT codes related to the CPB:

<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>37182</td>
<td>Insertion of transvenous intrahepatic portosystemic shunt(s) (TIPS) (includes venous access, hepatic and portal vein catheterization, portography with hemodynamic evaluation, intrahepatic tract formation/dilatation, stent placement and all associated imaging guidance and documentation)</td>
</tr>
</tbody>
</table>

### HCPCS codes covered if selection criteria are met:

<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>A9583</td>
<td>Injection, Gadofosveset Trisodium, 1 ml [Ablavar, Vasovist]</td>
</tr>
<tr>
<td>C8900</td>
<td>Magnetic resonance angiography with contrast, abdomen</td>
</tr>
<tr>
<td>C8901</td>
<td>Magnetic resonance angiography without contrast, abdomen</td>
</tr>
<tr>
<td>C8902</td>
<td>Magnetic resonance angiography without contrast followed by with contrast, abdomen</td>
</tr>
</tbody>
</table>

### ICD-10 codes covered if selection criteria are met for MRA:

<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>D57.00 - D57.819</td>
<td>Sickle-cell disorders</td>
</tr>
<tr>
<td>I10 - I16.2</td>
<td>Hypertensive diseases</td>
</tr>
<tr>
<td>I70.1</td>
<td>Atherosclerosis of renal artery</td>
</tr>
<tr>
<td>I71.02</td>
<td>Dissection of abdominal aorta</td>
</tr>
<tr>
<td>I71.03</td>
<td>Dissection of thoracoabdominal aorta</td>
</tr>
<tr>
<td>I74.01 - I74.09</td>
<td>Embolism and thrombosis of abdominal aorta</td>
</tr>
<tr>
<td>I77.3 - I77.6</td>
<td>Other disorders of arteries and arterioles [aortoiliac stenosis]</td>
</tr>
<tr>
<td>K55.011 - K55.9</td>
<td>Vascular disorders of intestine [chronic mesenteric ischemia]</td>
</tr>
<tr>
<td>K76.6</td>
<td>Portal hypertension</td>
</tr>
<tr>
<td>Z91.041</td>
<td>Radiographic dye allergy status [contrast allergy, renal insufficiency]</td>
</tr>
</tbody>
</table>

### ICD-10 codes not covered for indications listed in the CPB for MRA:

<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>D35.00 - D35.02</td>
<td>Benign neoplasm of adrenal gland</td>
</tr>
<tr>
<td>O69.4xx0 - O69.4xx9</td>
<td>Labor and delivery complicated by vasa previa</td>
</tr>
<tr>
<td>Z13.6</td>
<td>Encounter for screening for cardiovascular disorders</td>
</tr>
<tr>
<td>Z52.4</td>
<td>Kidney donor</td>
</tr>
</tbody>
</table>

### ICD-10 codes covered if selection criteria are met for MRV:
Magnetic Resonance Angiography (MRA) and Magnetic Resonance Venography (MRV)

D68.0 - D68.9  Other coagulation defects
I82.0  Budd-Chiari syndrome
I82.1  Thrombophlebitis migrans
I82.220 - I82.221  Embolism and thrombosis of inferior vena cava
I82.3  Embolism and thrombosis of renal vein
K75.1  Phlebitis of portal vein

ICD-10 codes not covered for indications listed in the CPB for MRV:
I63.0 - I63.9  Cerebral infarction

Ferumoxytol-enhanced MRA and MRV - no specific code:

ICD-10 codes not covered for indications listed in the CPB for MRA:
I70.1  Atherosclerosis of renal artery
N18.1 - N18.9  Chronic kidney disease (CKD)

Lower extremity:

CPT codes covered if selection criteria are met:
73725  Magnetic resonance angiography, lower extremity, with or without contrast material(s)

HCPCS codes covered if selection criteria are met:
A9583  Injection, Gadofosveset Trisodium, 1 ml [Ablavar, Vasovist]
C8912  Magnetic resonance angiography with contrast, lower extremity
C8913  Magnetic resonance angiography without contrast, lower extremity
C8914  Magnetic resonance angiography without contrast, followed by with contrast, lower extremity

ICD-10 codes covered if selection criteria are met for MRA:
I74.3  Embolism and thrombosis of arteries of the lower extremities
I79.8  Disorders of arteries, arterioles and capillaries in diseases classified elsewhere

ICD-10 codes not covered for indications listed in the CPB for MRV:
I80.10 - I80.299  Phlebitis and thrombophlebitis of other and unspecified deep vessels of lower extremities
I82.401 - I82.5z9  Acute and chronic embolism and thrombosis of deep veins of lower extremities

Upper extremity:

Other CPT codes related to the CPB:
72159  Magnetic resonance angiography, spinal canal and contents, with or without contrast material(s)
Magnetic Resonance Angiography (MRA) and Magnetic Resonance Venography (MRV)

<table>
<thead>
<tr>
<th>73225</th>
<th>Magnetic resonance angiography, upper extremity, with or without contrast material(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><strong>ICD-10 codes not covered for indications listed in the CPB for MRV:</strong></td>
</tr>
<tr>
<td>I80.8</td>
<td>Phlebitis and thrombophlebitis of other sites</td>
</tr>
<tr>
<td>I82.a11 - I82.a19</td>
<td>Acute embolism and thrombosis of axillary veins</td>
</tr>
<tr>
<td>I82.601 - I82.729</td>
<td>Acute and chronic embolism and thrombosis of superficial and deep veins of upper extremity</td>
</tr>
</tbody>
</table>

The above policy is based on the following references:

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Amendment to
Aetna Clinical Policy Bulletin Number: 0094 Magnetic Resonance Angiography (MRA) and Magnetic Resonance Venography (MRV)

There are no amendments for Medicaid.

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