Novel Multimodality Imaging Techniques for Diagnosis and Evaluation of Arteriovenous Malformations

Maxim Mokin, MD, PhD, Travis M. Dumont, MD,
Elad I. Levy, MD, MBA*

KEYWORDS

- Arteriovenous malformation • Digital subtraction angiography
- Computed tomography • Perfusion • Magnetic resonance imaging

KEY POINTS

- Dynamic time-resolved computed tomography (CT) or magnetic resonance angiography can visualize important hemodynamic features of arteriovenous malformations (AVMs), such as feeding arteries or early venous drainage.
- CT perfusion can help identify local pathologic phenomena, such as arterial steal and venous congestion, that can cause ischemic or hemorrhagic complications.
- Digital subtraction angiography (catheter angiography) remains the gold standard in AVM evaluation.
- In parametric imaging, an entire digital subtraction angiographic image sequence (arterial, capillary, and venous phases of radiographic contrast filling) is converted into a single composite color image.
- Both invasive and noninvasive intraoperative imaging techniques are available to determine the presence of a residual AVM during open surgical resection.

Financial relationships/potential conflicts of interest: Dr Dumont has no conflicts to disclose. Dr Levy receives research grant support, other research support (devices), and honoraria from Boston Scientific Corporation; receives research support from Codman & Shurtleff, Inc. and ev3/Covidien; has ownership interests in Intratech Medical Ltd. and Mynx/AccessClosure, Inc.; is a consultant for Codman & Shurtleff, Inc., ev3/Covidien, and TheraSyn Sensors, Inc.; and receives fees for carotid stent training from Abbott Vascular and ev3/Covidien. Dr Mokin has received an educational grant from Toshiba Medical Systems Corporation.
Department of Neurosurgery, Gates Vascular Institute-Kaleida Health, University at Buffalo, State University of New York, 100 High Street, Suite B4, Buffalo, NY 14203, USA
* Corresponding author.
E-mail address: elevy@ubns.com

Neurol Clin 32 (2014) 225–236
http://dx.doi.org/10.1016/j.ncl.2013.07.006 neurologic.theclinics.com

INTRODUCTION

Brain arteriovenous malformations (AVMs) are abnormal communications between cerebral arterial supply and venous drainage that form a nidus. Their defining hallmark is shunting of blood flow from brain arteries to large veins, noted radiographically by early venous drainage. Diagnostic imaging is of chief importance for managing brain AVMs. Estimation of risk for rupture and hemorrhage and determination of treatment strategy (surgical, radiosurgical, endovascular, or a combination of these) rely on an understanding of the location and angioarchitecture of a patient's AVM.

Traditionally, AVM was diagnosed using basic noninvasive studies, such as noncontrast computed tomography (CT) and magnetic resonance (MR) imaging, followed by CT or MR angiography, to differentiate AVMs from developmental venous anomalies, intracranial aneurysms, or other vascular lesions. Catheter-based digital subtraction angiography was then performed to confirm the diagnosis and characterize the hemodynamic properties of the AVM.

Over the past decade, several novel CT- and MR-based noninvasive imaging modalities have emerged, allowing more detailed evaluation of these complex lesions and providing hemodynamic profiles of abnormal vessels (feeding pedicles, draining veins) that could not be detected previously. This article reviews these modern imaging techniques and discusses their application in various clinical settings. The current role of catheter angiography in the diagnosis and treatment of AVMs is also reviewed, and grading scales that are used to characterize rupture and assess perioperative risk are compared. Finally, novel intraoperative imaging approaches used for AVM treatment are discussed.

INCIDENCE AND NATURAL HISTORY

The incidence of brain AVMs remains unclear[1,2] but has been estimated to be as high as 0.5% based on autopsy data.[3] AVMs typically present with neurologic symptoms but may be diagnosed incidentally. They generally cause symptoms such as hemorrhage or seizure, but also may have clinical manifestations from mass effect and ischemia. Ruptured vascular malformations are generally treated because of the risk of rerupture,[4,5] which is highest during the 5 years after the first presentation with hemorrhage. The annual rupture risk in patients with symptomatic but untreated AVMs has been reported to be between 2% and 4%,[5,6] and treatment of unruptured AVMs is frequently offered to avoid perceived risk of future hemorrhage. Treatment is also sought for unruptured but symptomatic AVMs to abate symptomatology, including seizure, mass effect from hydrocephalus,[7,8] cranial neuropathy,[9,10] and ischemia.[11]

NOVEL IMAGING MODALITIES

Whole-Brain CT Angiography and Perfusion Imaging

Whole-brain CT angiography and perfusion imaging for evaluating patients with AVMs became available after the introduction of a 320-detector row CT scanner capable of evaluating the whole brain. It combines dynamic time-resolved 3-dimensional CT angiography (thus called *4-dimensional* [*4D*] *CT angiography*) of the brain with whole-brain CT perfusion imaging that can be performed simultaneously.[12] This technique provides excellent spatial resolution and allows recognition of important AVM properties, including identifying feeding arteries and distinguishing them from normal arteries, and showing arteriovenous shunting and early venous filling.[13,14]

Because of its noninvasive nature, whole-brain CT angiography in combination with perfusion imaging is now widely used to evaluate patients with suspected AVMs (eg, in