Magnetic Resonance Angiography of the Upper Extremity

Peter Bannas, MD[a,b,*], Christopher J. François, MD[a],
Scott B. Reeder, MD, PhD[a,c,d,e,f]

KEYWORDS

• Magnetic resonance imaging • MR angiography • MRA • Contrast-enhanced MRA
• Upper extremity • Peripheral arteries

KEY POINTS

- Magnetic resonance angiography (MRA) can provide excellent image quality with high spatial resolution of the vessels of the upper extremity.
- Time-resolved MRA can be used to depict the flow dynamics of pathology to the upper extremity in the same way that digital subtraction angiography (DSA) provides functional information about vascular pathology.
- Practicing radiologists should be familiar with MRA imaging techniques used for individual cases to establish a correct diagnosis.
- MRA techniques must to be tailored for each individual to achieve optimal image quality and maximal diagnostic yield.
- Contrast-enhanced MRA (CE-MRA) techniques are currently preferred to noncontrast MRA techniques for imaging the upper extremity.

INTRODUCTION

MRA is a noninvasive imaging modality with high spatial resolution that can be used for diagnosis and treatment planning of vascular abnormalities of the upper extremity.[1,2] Unlike CT angiography (CTA) or DSA, it avoids the need for ionizing radiation and exposure to iodinated contrast agents. Targeted MRA of anatomic regions, such as the hand, can achieve high spatial resolution and in some instances may surpass the performance of CTA. In addition, the high attenuation of bone necessitates the need for complex postprocessing algorithms that segment bone from CTAs, because bone can obscure the visualization of small arteries of the distal extremities. DSA has the highest spatial and temporal resolution and remains the standard of reference for imaging the upper extremity. Recent developments in MRA, however, including time-resolved imaging, have made dynamic imaging of the vasculature feasible in the clinical setting to assess the anatomic and hemodynamic abnormalities seen in vascular disease and to bring MRA closer to the DSA reference standard.[1]

The Authors have nothing to disclose.

[a] Department of Radiology, University of Wisconsin-Madison, 600 Highland Avenue, Madison, WI 53792-3252, USA; [b] Department of Radiology, University Hospital Hamburg-Eppendorf, Martinistrasse 52, Hamburg 20246, Germany; [c] Department of Biomedical Engineering, University of Wisconsin-Madison, 1415 Engineering Drive, Madison, WI 53706, USA; [d] Department of Medical Physics, University of Wisconsin-Madison, 1111 Highland Avenue, Madison, WI 53705-2275, USA; [e] Department of Medicine, University of Wisconsin-Madison, 1685 Highland Avenue, Madison, WI 53705-2281, USA; [f] Department of Emergency Medicine, University of Wisconsin-Madison, 600 Highland Avenue, Madison, WI 53792, USA
* Corresponding author. Department of Radiology, University of Wisconsin-Madison, 600 Highland Avenue, Room E1/372, Madison, WI 53792-3252.
E-mail address: p.bannas@uke.de

Magn Reson Imaging Clin N Am 23 (2015) 479–493
http://dx.doi.org/10.1016/j.mric.2015.04.004

mri.theclinics.com

MRA of the upper extremity can be performed with or without the use of contrast agents. Although CE-MRA is generally preferred, non–contrast-enhanced techniques are increasingly available and may be a good option for patients with impaired renal function or who have allergies to gadolinium-based contrast agents (GBCAs). Non–contrast-enhanced techniques often overestimate stenoses in the setting of complex vessel anatomy or abnormal blood flow and can be time consuming. CE-MRA is robust and less time consuming. A major challenge for all CE-MRA techniques is to achieve optimal timing of the contrast bolus relative to the sampling of the center of *k*-space, which is crucial for optimal imaging. The specific MRA protocol chosen should be tailored to the patient to provide the best possible image quality.

A broad spectrum of vascular disorders of the upper extremity, ranging from the thoracic outlet syndrome to distal disease, such as thromboangiitis obliterans and hypothenar hammer syndrome, can be assessed accurately using MRA of the upper extremity. This review discusses MRA techniques and MRA findings of common disease entities of the upper extremity.

MRA TECHNIQUES

The main requisite for diagnostic MRA is to achieve sufficient spatial resolution and sufficient vessel contrast.[3] A high-field magnetic resonance (MR) scanner (1.5T or 3T) with modern phased-array receive coils is necessary to obtain images with high spatial resolution and high signal-to-noise ratio, while still covering the region of interest. Dedicated phased-array extremity or wrist coils should be used whenever possible, depending on the region of interest and required coverage.

Contrast-Enhanced MRA Techniques

Contrast-enhanced MRA

Of all available methods, CE-MRA has evolved as the preferred technique for MR imaging of the arterial vasculature.[3] CE-MRA relies on the T1 shortening effect of paramagnetic GBCAs. This results in a significant difference in signal intensity between blood and adjacent tissue when using heavily T1-weighted arterial-phase imaging.[3] The image acquisition must be timed with the contrast bolus peak during the sampling of the center of *k*-space to achieve maximum vessel contrast. Before the contrast material is injected, a nonenhanced acquisition with the same sequence settings as the contrast-enhanced scans can be acquired to allow for subtraction with the subsequent arterial-phase images. Subtracted images can be further manipulated with a maximum intensity projection (MIP) visualization to produce 3-D representations of the arterial anatomy.[2] Recent approaches in the lower extremity using Dixon-based methods are an alternative approach that can be used to suppress background fat signal potentially obviating subtraction.[4] This approach is promising for lower extremity MRA and also may be helpful for MRA of the upper extremity.

The advantages of CE-MRA include short scan times and high spatial resolution with minimal flow-related artifacts.[2] CE-MRA findings are highly reproducible, and image quality is comparable to that of DSA.[5] The main disadvantage of CE-MRA is the need for injection of GBCA, which has been associated with nephrogenic systemic fibrosis (NSF) in patients with renal insufficiency.[6] Overall, however, the safety profile of GBCAs is excellent and generally exceeds that of iodinated agents.[7]

Time-resolved MRA

Temporal resolution can add clinically valuable information to an examination of the upper extremity, including collateral flow pathways associated with stenoses and visualization of arterial to venous shunting. Another major advantage of time-resolved imaging is that it obviates a timing bolus or real-time fluorotriggering techniques. In this way, time-resolved imaging provides a point-and-shoot approach that is highly advantageous for imaging challenging anatomy where bolus timing/triggering methods are impractical.[8]

Most time-resolved MRA techniques use view-sharing methods to achieve high temporal resolution while maintaining high spatial resolution.[9] Such approaches use frequent sampling of low spatial frequencies (center of *k*-space) with less frequent sampling of higher spatial frequencies (periphery of *k*-space) that are subsequently shared between the final reconstructed 3-D data sets. These methods are commonly used in combination with subtraction, obtained by acquiring a precontrast mask, ultimately providing a set of time-resolved 3-D data images showing progressive enhancement of vessels akin to DSA. A major advantage is that not only morphologic but also dynamic information is obtained, which may allow for evaluation of the hemodynamic relevance of a stenosis. From the rapidly acquired multiple images, the best arterial or other relevant phase can be chosen. Time-resolved MRA can be performed in the same imaging session together with high-resolution standard MRA for more detailed depiction of small vessels.