Noncontrast Magnetic Resonance Angiography
Concepts and Clinical Applications

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KEYWORDS

• MR angiography • Noncontrast • Nephrogenic systemic fibrosis • Fast spin echo
• Balanced steady-state free precession • Arterial spin labeling • Time of flight • Phase contrast

KEY POINTS

- Noncontrast magnetic resonance angiography (NC-MRA) techniques offer safe, noninvasive imaging, which is of particular importance in patients with impaired renal function, or in whom intravenous access is challenging.
- NC-MRA techniques are classified into 3 main categories, which obtain arterial signal from (1) flow-related enhancement, (2) the phase of magnetic resonance (MR) imaging signal from moving blood, and (3) the MR imaging physical properties of blood, independent of blood flow.
- Selection of the appropriate NC-MRA technique depends on the properties of the vascular bed of interest, the disorder being studied, and an understanding of each technique's specific strengths and weaknesses.

Video of respiratory navigator inflow inversion recovery magnetic resonance angiography accompanies this article at http://www.radiologic.theclinics.com.

INTRODUCTION

Magnetic resonance (MR) angiography (MRA) is commonly used clinically, allowing noninvasive, accurate, and comprehensive vascular assessment from head to foot, without ionizing radiation. T1-weighted contrast-enhanced MRA (CE-MRA) performed with a gadolinium chelate[1] is the mainstay of thoracoabdominal and peripheral MRA, with large coverage, high spatial resolution, and rapid acquisition. Time of flight (TOF) MRA and phase contrast (PC) MRA are common noncontrast MRA (NC-MRA) techniques used in neurovascular imaging. However, NC-MRA has not historically been widely used in other vascular beds.

With gadolinium identified in 2006 as a potential causative factor in nephrogenic systemic fibrosis (NSF),[2] multiple NC-MRA techniques have been developed. Contrast dose minimization and restrictions on the use of less stable agents in vulnerable patients[3] have decreased NSF incidence. However, NC-MRA techniques avoid all contrast risks, offering a safe alternative in pregnant patients, or in patients in whom intravenous access

Disclosures: Royal Australian and New Zealand College of Radiology research grant, Diabetes Australia research trust grant, Austin Medical Research Foundation grant (R.P. Lim). American Heart Association grant-in-aid (12GRNT12080013), research support from Siemens Healthcare (I. Koktzoglou).
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Radiol Clin N Am 53 (2015) 457–476
http://dx.doi.org/10.1016/j.rcl.2014.12.003
0033-8389/15/$ – see front matter

cannot be obtained. NC-MRA is also desirable for economic reasons, because gadolinium can add substantially to MR imaging costs in certain countries. The main challenges of NC-MRA are long acquisition time and concerns about technique robustness.

This article reviews basic properties of blood as background to selection and implementation of NC-MRA techniques. Commercially available and upcoming techniques are reviewed, with a summary of existing clinical experience, providing a framework for their incorporation into clinical practice.

PROPERTIES OF BLOOD

T1 and T2 Relaxation Properties

The longitudinal (T1) and spin-spin (T2) relaxation times of blood profoundly influence the MR imaging techniques used to perform noncontrast MRA. The T1 of blood depends on the main magnetic field strength (B0) and is approximately 1200 milliseconds at 1.5 T[4] and 1600 milliseconds at 3.0 T.[5] The T2 of blood depends on its oxygenation level and is approximately 250 milliseconds for well-oxygenated arterial blood. Deoxygenated, venous blood can have a T2 as low as 100 milliseconds.

Blood Flow

Vascular resistance (primarily influenced by vessel caliber), and the pressure gradient between proximal and distal ends of the vessel determine flow, defined as volume per unit time.[6] In normal large vessels, blood flow is laminar, with a parabolic profile such that the fastest velocity is present centrally within the lumen. Other flow variations include plug flow at the origins of visceral vessels, with constant blood flow across the entire luminal diameter; flow separation at vessel bifurcations leading to formation of vortices; and turbulent flow, where flow is chaotic, as seen in diseased vessels just beyond sites of stenosis. With turbulent flow and vortices, there is variation in speed and direction of flow, with potential signal nulling from phase dispersion of blood spins.[7] In arteries, flow is pulsatile, because of their elasticity and high resistance of downstream arterioles. Approximately one-third of arterial blood flow is transmitted during systole and two-thirds during diastole.[6] Vascular resistance affects arterial waveforms across the body, with persistent forward flow in diastole in low-resistance vascular beds such as the internal carotid and renal arteries. In peripheral arteries where vascular resistance is high, a triphasic waveform with flow reversal is present (**Fig. 1**). Venous flow is lower[8] and more constant, only fluctuating with changes in intrathoracic pressure during respiration.

Velocity, distance per unit time, is an important component of flow. Peak systolic velocity (PSV),

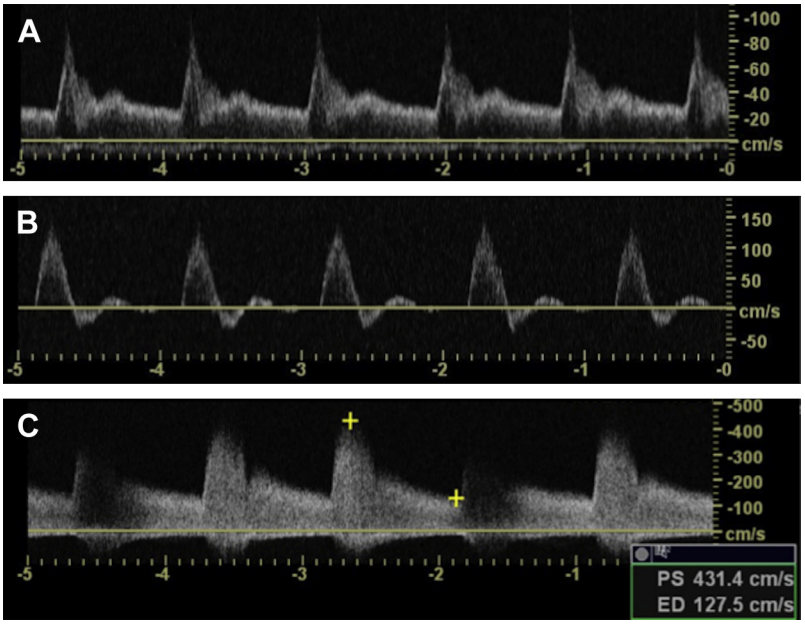

Fig. 1. Duplex Doppler ultrasonography waveforms of (*A*) normal internal carotid artery (ICA), with persistent forward flow throughout the cardiac cycle; (*B*) normal common femoral artery with triphasic waveform, including late systolic flow reversal and forward flow in early diastole; and (*C*) severe (70%–79% by Doppler criteria) ICA stenosis, with increased peak systolic (PS) and end-diastolic (ED) velocities, and spectral broadening indicating turbulent flow.