Male Pelvic MR Angiography

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KEYWORDS

• MR angiography • Male pelvis • Gadofosveset • May-Thurner • Testicular varicocele • Priapism • USPIO • Nanoparticles

KEY POINTS

- Magnetic resonance (MR) angiography is a powerful tool in evaluating anatomy and pathology when applied to the male pelvis. MR angiography produces high-quality images of the arterial system approaching the resolution of CT angiography, without ionizing radiation.
- Additional advantages include the ability to obtain angiographic images in the absence of contrast material with non–contrast-enhanced MR angiographic techniques, which may be necessary in patients with renal disease or with allergy.
- The recent introduction of blood pool contrast agents, such as gadofosveset, has significantly improved the quality of imaging of the venous system, because it is no longer dependent on the first-pass imaging. Steady state imaging with blood pool contrast agents allows for the acquisition of superior-quality high-resolution images and other time-intensive techniques.
- The extended imaging time also allows for the testing for functional consequences of provocative maneuvers.

INTRODUCTION

The male pelvis is complex anatomically and contains many structures unique to the male anatomy, including the penis, scrotum, testicles, seminal vesicles, and prostate gland, as well as structures present in all humans, such as the bladder and rectum. These structures are dependent on a complex network of blood vessels to both supply the organs with blood and return the blood to the circulatory system. Perturbations of the vascular network can lead to diminished function of the male pelvic organs, including erectile dysfunction and diminished fertility. In extreme cases, disruption of blood flow can lead to catastrophic consequences, such as tissue loss and necrosis, as in testicular torsion or ischemic priapism. Examination of the male pelvic vasculature thus may provide valuable insight into male pelvic pathology as well as help with surgical or endovascular treatment planning. This article explores the use of MR angiography in the examination of the male pelvis.

MR angiography is a noninvasive technique, much like CT angiography, that can provide detailed characterization of the male pelvic vasculature. The main advantage of MR angiography is the lack of ionizing radiation, which means it can be performed in younger patients and repeated examinations can be done without concern for the deleterious consequences associated with ionizing radiation. Several additional advantages include the ability to perform noncontrast imaging, which can provide information on velocity and direction of blood flow and can be performed in patients with iodinated contrast allergy and those with kidney disease. In addition, the recent introduction of blood pool contrast media allows for steady state imaging, which can be used for provocative maneuvers as well as high-resolution image acquisition.

NON–CONTRAST-ENHANCED MR ANGIOGRAPHY

Non–contrast-enhanced MR angiography, unlike conventional x-ray angiography and CT angiography, does not require intravenous contrast administration. Instead, unenhanced MR

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angiography takes advantage of the physiologic flow of blood to construct images based on flow-induced signal variations to characterize the lumen of blood vessels. Unenhanced MR techniques create images based on 2 basic characteristics of blood flow that relate to the signal of flowing blood relative to the stationary spins of static tissue. The first is referred to as amplitude effects, where the blood flowing into a chosen slice has a different longitudinal magnetization from the stationary tissue in the given slice. The signal intensity is dependent on the duration of the blood in the slice. The other characteristic is phase effects, which refers to the changes in transverse magnetization that occur as blood flows along the magnetic field gradient compared with the stationary spins of static tissue.[1,2]

Time of Flight

Amplitude effects are the basis of time-of-flight (TOF) imaging. A given slice (2-D) or slab (3-D) is selected and the stationary tissue is saturated using gradient-echo sequences with very short repetition times reducing the signal from the stationary tissue. Flowing blood, in contrast, has not been saturated and thus has high signal relative to the saturated stationary tissue. The amplitude of the signal is related to the duration of the blood in the slice, or TOF. Thus, the signal intensity is related to the velocity of the blood flow, with higher velocity flow yielding higher signal intensity. The angle of the flow through the selected slice also contributes to signal intensity. Flow perpendicular to the slice has the shortest route through the slice leading to increased signal intensity.[1,2]

As described previously, blood flowing into the selected slice from either direction produces high signal intensity; thus, the acquired images have both arterial and venous signal. The same principle of saturation of tissue can be applied to selectively image either arterial or venous flow. Signal from inflow can be reduced through the use of presaturation bands. Presaturation bands applied upstream to the selected slice saturate arterial inflow, resulting in the selective imaging of venous blood flow. Alternatively, presaturation bands applied downstream to the selected slice nullify signal from the venous blood flow, resulting in the selective imaging of arterial flow.

TOF images can be acquired through the use of either 2-D or 3-D techniques. In the 2-D technique, a stack of sequentially acquired single slices forms the basis of the image. The advantage of the single slice technique is that it permits good saturation of the stationary tissue optimizing the inflow effect, which in turn allows for the imaging of even in slow flow vessels. This method is best for flow perpendicular to the plane, because vessels not running perpendicular or even running parallel are subjected to saturation and signal is lost.

3-D TOF acquires an entire imaging volume simultaneously, usually a slab 30- to 60-mm in thickness. The benefit of 3-D TOF is the high spatial resolution and high signal-to-noise ratio. An additional benefit is that vessels running parallel are better depicted than in the 2-D method. A drawback of 3-D acquisition is the length of time the blood remains in the saturated slab. The extended transit time in the saturated slab may result in decreased blood signal intensity from the repeated radiofrequency pulses, with slow flow at greatest risk for signal loss. This technique, therefore, requires careful selection of slab thickness to optimize for the region of interest. An additional technique, multiple overlapping thin-slab acquisition (MOTSA), was designed to have the advantages of both 2-D and 3-D TOF. MOTSA is less susceptible to the signal loss because of saturation with 3-D TOF due to the thin slabs used and retains the high spatial resolution and signal-to-noise ratio. Reduced susceptibility to signal loss due to thinner acquisition slabs comes at the cost of longer acquisition times.[1]

Phase Contrast

Phase-contrast angiography is based on phase effects to produce angiographic images. A bipolar gradient is applied in gradient-echo acquisitions. Stationary tissue is dephased and rephased to its original state, whereas moving tissue dephases in proportion to the flow velocity. Because the encoding gradients are defined to encode flows within a certain velocity range, the operator must determine the anticipated velocity to choose the appropriate encoding gradient because velocities outside of the range are poorly encoded.[1,2]

Phase-contrast acquisitions allow for the detection of flow in any plane in 3-D space. This is accomplished by repeating the encoding in the X, Y, and Z axes. The images acquired from the 3 axes are then summed and subtracted from reference images performed without encoding gradient, leaving only the images of vessels. In addition, flow velocity can be determined noninvasively with phase-contrast imaging when the slice acquisition is perpendicular to the direction of blood flow. Flow rate can then be calculated from the product of the vessel area and flow velocity.[2]

CONTRAST-ENHANCED MR ANGIOGRAPHY

Gadolinium-Based Contrast Agent

Classically, contrast-enhanced MR angiography has been performed with extracellular contrast