Utility of magnetic resonance imaging in establishing a venous pressure gradient in a patient with possible nutcracker syndrome

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Nutcracker syndrome is characterized by abnormal acute angulation of the superior mesenteric artery origin from the aorta, with resulting compression and hypertension of the crossing left renal vein. The radiologic studies used in diagnosis are typically limited to standard cross-sectional anatomic imaging with computed tomography or magnetic resonance imaging, with occasional use of Doppler ultrasound imaging for hemodynamic quantification. The standard for acquiring anatomic and physiologic information continues to be invasive venography. We describe the successful novel application of phase-encoded magnetic resonance imaging as a noninvasive method for acquiring anatomic and hemodynamic data in a case of possible nutcracker syndrome in a young patient. (J Vasc Surg Cases 2016;2:80-3.)

Nutcracker syndrome, characterized by abnormal acute angulation of the superior mesenteric artery (SMA) origin from the aorta, with resulting compression and hypertension of the crossing left renal vein (LRV), is an uncommon but important disease to recognize in clinical practice. Hematuria is the most common symptom and results from rupture of thin-walled varices caused by elevated venous pressure into the collecting system. Pelvic or flank pain is the next most common symptom. Additional complications include proteinuria and varicoceles.[1,2]

In addition to careful clinical history and examination, radiologic imaging studies include Doppler ultrasound (DUS) imaging with velocity measurements[3-5] and visualization of LRV compression on cross-sectional computed tomography (CT) or magnetic resonance imaging (MRI).[6-8] Use of DUS imaging in diagnosis and treatment guidance is somewhat hampered by limitations associated with acquisition of both gray scale and Doppler images, including technologist variability, limited sonographic "windows," alteration of flow from transducer compression, and angle-dependent artifacts.[3,9,10] In addition, the required anatomic information requires a separate cross-sectional imaging examination with MRI or CT. Characteristic MRI or CT findings include narrowing of the crossing LRV at the SMA, with engorgement of the tributaries (varicoceles). Normal LRV diameters are generally 4 to 5 mm, with a ratio of distended-to-narrowed diameter of up to 4:1, although significant normal variations make reliance on these anatomic quantities of uncertain clinical significance.[3,11]

The definitive test is considered renal vein venography with measurement of pressure gradient. It is, however, invasive and requires exposure to both radiation and contrast material. A normal pressure gradient between the inferior vena cava and the LRV is ≤1 mm Hg. Values of ≥3 mm Hg have been more consistently correlated with nutcracker symptoms and are considered to represent hemodynamically significant LRV hypertension.[12-14] Phase-contrast MRI (PC-MRI), also known as velocity-encoded MRI, is an MRI technique in which vascular flow velocities can be determined. PC-MRI has been established as a gold standard noninvasive method for evaluation of cardiac and great vessel pressure gradients,[15,16] with multiple studies also demonstrating utility in evaluation of peripheral and splanchnic vasculature.[17-19] Of note, no gadolinium contrast is needed for this technique. We describe the use of MRI to measure the pressure gradient across the LRV with comparison with contrast venography. Written consent was obtained from the patient for publication of this case report and accompanying images.

CASE REPORT

A 24-year-old Caucasian woman presented with chronic pelvic congestion syndrome, interstitial cystitis, and endometriosis. Her pain was nearly constant, located in the left lower quadrant, and exacerbated by prolonged sitting or standing and after exercise. The pain radiated down the left inner thigh. She also reported dyspareunia. About 1 year ago, she also developed left upper quadrant pain that required multiple hospitalizations for pain control. Imaging at that time revealed markedly dilated left ovarian and uterine veins, and coil embolization of the left ovarian vein was performed at another hospital.

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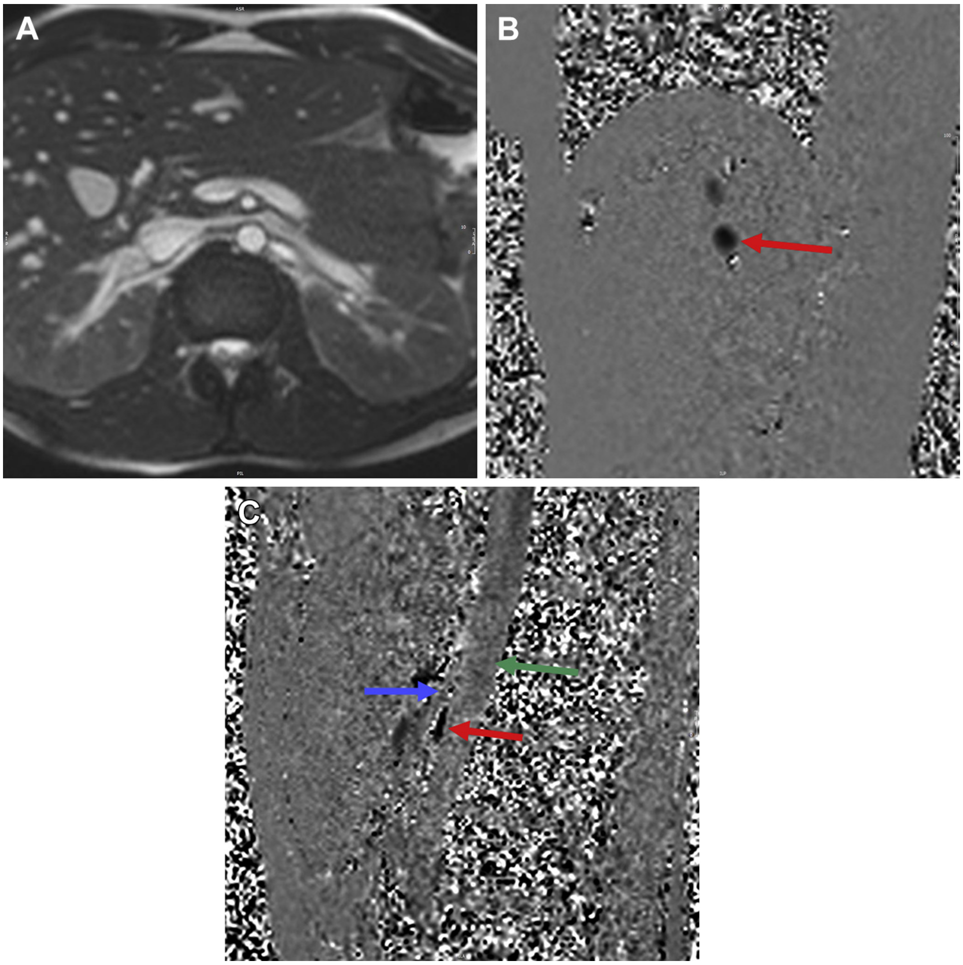

Fig 1. A, Axial two-dimensional bright-blood images demonstrate compression of the left renal vein (LRV) by the superior mesenteric artery (SMA). Cross-section phase-contrast magnetic resonance images (PC-MRI) of the **(B)** peripheral and **(C)** central LRV images (*red arrows*) demonstrate a minimum diameter decrease from 1.5 cm to 0.5 cm in the central LRV compared with the peripheral LRV. The *green arrow* indicates the aorta, and the *blue arrow* indicates the SMA.

However, there was no significant symptom relief, and she presented to our institution. An MRI from another hospital demonstrated tight compression of the LRV with dilation of mesenteric collaterals after left ovarian vein ligation. Results of urinalysis were negative, however. Hemodynamic evaluation of the LRV was deemed necessary to help determine if management should be focused upon alleviation of possible persistent nutcracker syndrome as the etiology. Additional velocity-sensitive MRI was then suggested.

MRI. A noncontrast MR angiography evaluation of the abdomen was performed on a 1.5-Tesla MRI machine (Fig 1). Axial and coronal balanced steady-state images of the abdomen and pelvis were acquired for anatomic evaluation of the arterial and venous structures and for planning of the flow-quantification sequences. These images depict flowing blood as "bright" and are often called "bright-blood images." Velocity-encoding scout images were acquired in the peripheral LRV, $\sim$1 cm from the renal hilum and at the SMA crossing. These images determine if the parameters controlling velocity measurement are sufficient to measure the maximum velocity present in that vessel cross section. A velocity that is too high results in "aliasing," which is a misrepresentation of higher velocities as incorrectly low velocity or noise. Because no aliasing was seen with a velocity-encoding maximum of 20 cm/s and 80 cm/s in the respective locations, these were used in through-plane flow sequences that measure the bulk flow and maximum velocity through a particular cross section. Through-plane quantification of flow and velocities was performed by dedicated three-dimensional laboratory technologists using Circle software (Wayne, NJ; Fig 2).

Pressure gradient calculation. The modified Bernoulli equation was used to calculate the pressure gradient across the compressed LRV segment as $4v^2$, where v is the velocity across the stenosis. Therefore, the estimated pressure gradient caused by the SMA narrowing in this patients is: $4 \times (0.78\ \text{cm}^2) = 2.44$ mm Hg.

Venography. A confirmatory LRV venography was obtained via right common femoral vein access. A 5F glide catheter was