Identification of aortic thrombus by magnetic resonance imaging

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The unique properties of magnetic resonance imaging result in the potential to differentiate various components of the diseased arterial wall. In this article four cases are presented in which magnetic resonance imaging showed mural aortic thrombus and its anatomic relationship to the visceral and renal arteries. Once thrombus is identified and localized specific operative strategies can be undertaken to prevent recurrent embolic events and/or avoid perioperative thromboembolic complications. (J Vasc Surg 1989;9:801-5.)

Adherent thrombus is a common finding along the irregular surface of advanced atherosclerotic plaque and may embolize either spontaneously or during surgical manipulation of the aorta. Neither angiography nor ultrasonography can reliably detect aortic thrombus in nonaneurysmal atherosclerotic disease. Recently we have successfully used magnetic resonance imaging (MRI) to identify adherent aortic thrombus in four patients. The specificity of MRI in discriminating soft tissue is a result of differences in the density and the chemical environment of the hydrogen nuclei in these various tissues. These are sufficiently unique to thrombus as compared to plaque so that a clear differentiation usually can be made. Magnetic resonance imaging may be an important and useful adjunct to conventional aortography in the evaluation of patients with spontaneous lower extremity embolic events and in the identification of patients who may be at increased risk for embolization during aortic surgery.

MATERIAL AND METHODS

Basic principles of MRI

Hydrogen nuclei are the primary source of the MRI signal. They have magnetic dipole moments, as bar magnets have, and when placed in a magnetic field, they gain a net alignment with the field. However, bursts of radio waves of an appropriate frequency will alter this alignment and cause a phenomenon referred to as excitation. After each burst the nuclei resume their original alignment with the magnetic field. This realignment is referred to as relaxation and is associated with the emission of radiofrequency energy. The intensity and characteristics of this emitted signal depend on a number of factors including the density and the relaxation parameters (T1 and T2) of the molecules containing the nuclei under study. The exponential time constant (T1) reflects the time that is required to recover equilibrium after excitation. The detected signal decays exponentially with time. The characteristic time constant describing this signal decay is the transverse relaxation parameter, T2.

A variety of imaging techniques shape the magnetic field to encode position through the unique relationship of magnetic field and resonant frequency. Clinical work is done almost universally by means of a technique called 2D-FT (two-dimensional Fourier transformation) multisection imaging. Two kinds of images can be reconstructed from the 2D-FT process. One is called a magnitude image and shows signal intensity. The second is called a phase image and is a reliable indicator of flow. It is necessary to use both of these images to obtain an accurate image of the vascular system.

The intensity of the magnetic resonance signal from an imaged tissue volume is related to the local hydrogen content and the local molecular environment. Nuclei in blood moving with a velocity of greater than 10 to 15 cm/sec undergo a disrupted imaging sequence, which reduces the signal to near background levels and causes the vessel lumen to
Fig. 1. A, Cross-sectional magnitude image of the aorta from patient 1. Note the vertebral body (a) and the left renal vein (b). Within the aorta there is a rim of heavily calcified plaque that gives off very little signal and appears dark. This is lined by a thrombus of high signal intensity (arrow). Note the irregular contour of the flow channel through the thrombus, a phenomenon seen occasionally in these studies. The vena cava is seen below and to the side of the aorta. B, Subtraction aortogram from the same patient shows some irregularity of the infrarenal aorta, with an occlusion of the right common iliac artery (arrow). The thrombus and erratic lumen shown in the MRI study are not apparent.

Magnetic resonance imaging

Magnetic resonance imaging scans reported here were performed on a 0.35-tesla superconducting system (Diasonics Inc, Milpitas, Calif.) by means of the dual-echo technique. The hydrogen resonance frequency was 15 MHz. Twenty dual-echo sections (40 images) were obtained in 17 minutes in a multisec-
tion sequence. Section thickness was 10 mm. Trans-
verse images were constructed by means of the 2D-
FT technique. These were displayed as an inferior
view with the patient supine.

Parameters set for the imaging sequences used in
these studies were as follows: TR (the time between
excitation pulses) was 2.0 seconds; the TE (the time
between excitation and sampling) was 30 msec and
60 msec. Two signal intensities were then obtained,
one at each TE. Using these two data points, we
calculated $T_2$ for plaque and thrombus and found it
to be unique for each tissue, $41 \pm 2$ msec for throm-
bus and $37 \pm 2$ msec for plaque. Because of the
longer decay time for thrombus, the difference in
intensity between plaque and thrombus was more
pronounced in the later (60 msec) sample. The
intensity ratios were $1.83:1.0$ at 30 msec and
$2.05:1.0$ at 60 msec. A longer TE amplified the dif-
ference between thrombus and plaque, but as the
signal decreased the background noise increased, and
image resolution was reduced.

CASE REPORTS

Case 1. A 75-year-old man was admitted to the hos-
pital with a history of bilateral calf claudication at 100 feet.
No lower extremity pulses were palpable and the ankle-
brachial index was 0.2 bilaterally. Aortography revealed
diffuse infrarenal aortic atherosclerosis with occlusion of
the right common iliac artery and left external iliac artery
(Fig. 1). An aortobifemoral bypass was performed by
means of an infrarenal aortic cross-clamp. At operation
atherosclerotic debris and adherent thrombus lined the
aorta, including the area where the clamp was applied. This
material was "flushed" out through the transected aorta,
and the aortofemoral bypass was done without incident.
Postoperatively urine output and serum creatinine were
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Fig. 2. A, Cross-sectional magnitude image of the midinfrarenal aorta from patient 2. The vertebral body (a) is well demarcated. There is minimal plaque in the aorta. The thrombus is seen as the area of intense signal apparently attached to the anterior aortic wall (arrow). B, Aortogram of patient 2 on admission to the hospital shows minimal irregularity in the midinfrarenal aorta. C, Arteriogram of the left iliac and femoral vessels shows left common femoral embolic occlusion (arrow).

initially normal but then deteriorated, and the patient experienced complete renal failure. Thorough evaluation failed to identify an infectious, immunologic, or toxic cause for the patient's renal failure, and an embolic shower was suspected. An MRI scan had been obtained preoperatively on this patient as part of a separate protocol. When it was reviewed postoperatively, adherent thrombus was seen surrounding both renal arteries (Fig. 1). This was not evident on the preoperative aortogram (Fig. 1).

Case 2. A 57-year-old man came to the hospital with acute arterial insufficiency of the left lower extremity. An aortogram with runoff views revealed minimal atherosclerotic disease, with embolic occlusion of the left common femoral artery and two small emboli to distal branches of the right profunda femoris artery (Fig. 2). The patient underwent successful left transfemoral embolectomy. There was no history of cardiac disease or arrhythmia and results of a subsequent echocardiogram were normal. An MRI study was done and detected extensive thrombus in the infrarenal aorta (Fig. 2). At operation thrombus was found arising from an ulcerated aortic plaque (Fig. 3). Eighteen months after an aortofemoral bypass, the patient experienced no further embolic events without anticoagulation.

Case 3. A 70-year-old man described an 8-month history of bilateral thigh and calf claudication on walking one block. No lower extremity pulses were found on examination. Aortography showed an infrarenal aortic occlusion without any apparent involvement of the renal artery orifices with thrombus. In contrast, the preoperative MRI study showed that mural thrombus did extend above both renal arteries (Fig. 4). Consequently when an aortofemoral bypass was performed, the suprarenal aorta was isolated with care, and clamps were applied to the suprarenal aorta and both renal arteries. The aorta was then transected, and
Fig. 4. A, Cross-sectional magnitude image of the aorta at the level of the right renal artery (black arrow) from patient 3. Thrombus is seen as a gray area in this aorta, with minimal atherosclerotic plaque in this perirenal aorta (white arrow). One can also identify vertebral body (a), left renal vein (b), and inferior vena cava (c) in this section. B, Aortogram of patient 3 shows infrarenal aortic occlusion (arrow) but minimal irregularity of perirenal aorta.

Fig. 5. A, Cross-sectional magnitude image of aorta at level of left renal vein (arrow) from patient 4. The vertebral body (a) and the vena cava (b) can be seen. The flow channel is seen as the dark center (arrow) surrounded by plaque and thrombus. The flow channel was somewhat larger than it appears in this image because of an artifact produced by turbulence primarily in the posterior portion of the aorta. The true luminal size was confirmed by phase image and by direct observation at surgery. B, Aortogram shows minimal reduction in lumen diameter at the point corresponding to the image in A (arrow).

the thrombus surrounding the renal artery ostia was removed. The aortic cross-clamp was then repositioned below the renal arteries, and flow was restored to both kidneys. The aortobifemoral bypass was completed, and the patient did well postoperatively with no evidence of renal or distal embolic phenomena.

Case 4. A 63-year-old woman had a 5-month history of bilateral calf claudication on walking one block. An aortogram showed diffuse aortoiliac disease (Fig. 5). The lower extremity pulses were diminished. A preoperative MRI scan identified thrombus extending above the renal artery ostia (Fig. 5), which was not seen on an angiogram.
Our operative approach was as outlined in the discussion of patient 3. Again, a large amount of thrombus and atheromatous debris was removed from the pararenal aorta and renal artery orifices. This patient also had an uncomplicated postoperative course.

**DISCUSSION**

Failure to detect nonocclusive mural aortic thrombus can have serious sequelae. Recurrent spontaneous embolization resulting in tissue loss may occur in spite of anticoagulation. In addition inadvertent manipulation of the thrombus-bearing aorta during reconstructive procedures can shower emboli to adjacent tissue beds. Obviously it would be very advantageous to identify such a lesion before either of these complications develops. Neither ultrasound imaging nor CT scanning can identify components of the aortic wall or plaque. Angiography is a luminal study, and as such can show only luminal irregularities, without providing any information on the histologic characteristics of the lesion. Biplanar aortography is more likely to detect such irregularities because of the two-dimensional views of the aorta. However, it still offers no differentiation as to the nature of the lesion.

The cases in this preliminary report illustrate the potential value of MRI in the detection of aortic thrombus and the impact of this information on the operative management of aortic atherosclerotic disease. The patients underwent MRI studies as part of a protocol investigating the utility of MRI in vascular disease. It is clear from these cases that MRI studies of the aorta can often differentiate mural thrombus from plaque. One potential problem is slowly moving blood along the aortic wall, which can give a signal similar to thrombus. This problem was addressed in these studies by use of phase images to determine the interface of lumen and wall. Whereas the reliability of this approach was not directly addressed, our operative examinations of the aorta verified the accuracy of the studies described in this report.

MRI has been reported by others to clearly identify aortic anatomy, the origins of the visceral vessels, and their relationship to thrombus or plaque.6 This information was used to make clinical decisions in the cases reported here. Because of the limited number of cases, further experience with MRI will be needed to fully assess its utility in this area. However, it seems clear that MRI can detect aortic mural thrombus and provide valuable ancillary data to conventional angiography.

**REFERENCES**


