Magnetic resonance imaging (MRI) and magnetic resonance angiography (MRA) play a critical role in diagnosing aortic disease such as aortic dissection and aneurysm. Additionally, the advent of contrast-enhanced MRA has allowed MRA to advance markedly and several new imaging techniques to emerge as well. While computed tomography (CT) angiography using multidetector-row CT is a significant innovation, MRA may generate more useful diagnostic information, such as on the artery of Adamkiewicz.

Key words: magnetic resonance imaging, magnetic resonance angiography, aorta, aneurysm

INTRODUCTION

Magnetic resonance imaging (MRI) has advantages in that it does not need radiation exposure and it can obtain any oblique plane. It has been applied for the diagnosis of great vessel diseases for a long time. In addition, the advent of contrast-enhanced magnetic resonance angiography (MRA) promoted the development of high-speed pulse sequences suitable for MRA one after another, leading to rapid advancement in recent years. On the other hand, CT angiography (CTA) using multidetector-row CT (MDCT) has recently developed rapidly, competing with MRA. Based on this clinical background, the current status of MRI and MRA diagnosis of aortic disease is described.

IMAGING METHODS

1. MRI

Images are obtained employing the conventional spin echo (SE) or fast spin echo (FSE) sequence. When the ascending aorta is the main target of the imaging, ECG-gating technique is required to reduce the motion (pulsation) artifacts. MRI has the advantage in that the aortic wall and lumen can be observed without contrast medium (Fig. 1) and the acquisition of any oblique plane is available. On the other hand, long acquisition time compared to CT, motion artifacts due to respiration and pulsation are disadvantages of MRI. Moreover, flow related artifacts frequently appear in dilated lesions, such as aortic aneurysms. In such cases, the black blood technique, which inhibits the flow related signals, is useful.

2. Cine MRI

Images of multiple cardiac phases are acquired in the single slice using the ECG-gated gradient echo (GRE) technique. This technique is useful in that flow dynamics can be observed without contrast medium. For aortic disease, cine MRI may be used to evaluate the entry in aortic dissection. However, the single-slice acquisition is basically required, so the acquisition time may prolong obtaining the multiple plane images.

Cine image acquisition within several seconds per slice has recently become possible by employing true fast imaging with steady precession (FISP) and steady state free precession (SSFP) techniques, overcoming the disadvantage of a long acquisition time. The parallel imaging technique described below may also be applied.

3. MRA

For aortic diseases, contrast-enhanced MRA is generally used. Since contrast medium-associated T1-shortening of the blood signal is the principle of this imaging...
technique, contrast-enhanced MRA is able to obtain sufficient signals in bent and turbulent flow regions, which are likely to be insufficient by the time-of-flight (TOF) and phase contrast (PC) techniques which use no contrast medium.

In contrast-enhanced MRA, generally, contrast medium is rapidly injected at a rate of about 1–3 ml/sec, and the first pass of contrast medium is imaged. This method requires the detection of the timing that the contrast medium reaches the aorta, for which there are 3 techniques. One is the injection of a small volume of contrast medium prior to the main scanning to determine the time that the contrast medium reaches the target (test injection method). The second method involves setting a region of interest on the target vessel, and when the arrival of contrast medium is detected, image acquisition will automatically start (SmartPrep, GE). The third method is to start the acquisition after visually confirming the arrival of contrast medium using MR fluoroscopy technique (FluoroPrep, GE).

The acquisition time of contrast-enhanced MRA is usually about 30 seconds, which is applicable while breath-holding, and images without respiratory artifacts can be obtained (Fig. 2). Aortic aneurysm is a good indication, and the points of diagnosis are: 1) the location of aneurysms, 2) morphology of aneurysms (fusiform shape or saccular shape), 3) diameter, and 4) evaluation of the major aortic branches (anatomical relationship with the aneurysm, the presence of branch involvement, and patency of the three arch vessels for thoracic aortic aneurysms and the renal artery, inferior mesenteric artery, and common iliac artery, external iliac artery, and internal iliac artery for abdominal aortic aneurysms).

**VARIATION OF CONTRAST-ENHANCED MRA**

In addition to the popular method described above, various other techniques are available for contrast-enhanced MRA. Herein, 2 useful methods for the evaluation of aortic diseases are introduced.

1. **Slow infusion MRA**

Images are acquired over 1–5 minutes while contrast
medium is infused at about 0.2–0.3 ml/sec, and this method appeared in the original report of contrast-enhanced MRA. This method has the advantage in that high spatial resolution images can be obtained. In addition, it is not sensitive to the arrival timing of contrast medium compared with the conventional contrast-enhanced MRA. Accordingly, double barrel type aortic dissection, in which the blood flow speed differs between the true and false lumens, may be a good indication (Fig. 3). In a study performed at our institution, the diagnostic performance of this method had been compared with the conventional angiography (intra-arterial distal subtraction angiography, IA-DSA) as a gold standard in patients with aortic dissection. The diagnostic performance became comparable to that of IA-DSA with the presence of dissection, the detection of the entry, the origination of the major branches from the true or false lumen, and its involvement to the branches. In addition, this method is applicable to neonates and infants who cannot hold their breath, and the aortic arch anomaly is a good indication.

Disadvantages of this method are contamination of the veins and motion artifacts due to respiration and pulsation.

2. Time-resolved MRA

This is to carry out MRA with higher temporal resolution employing a very short repetition time (TR) and echo time (TE). Images are consecutively acquired at an acquisition time of about 10 seconds per image with rapidly injecting contrast medium, and first pass of the contrast medium is sequentially observed. For aortic diseases, this technique is applied to investigate blood flow

Fig. 3 A 62-year old man with chronic Stanford type B dissection.
A: A 3-dimensional volume rendering (VR) MRA image shows the anatomical relationship between the true and false lumen.
B: An oblique sagittal partial maximum intensity projection (MIP) MRA image shows the entry as a defect of the intimal flap (arrow).
C: An oblique coronal multiplanar reconstruction (MPR) MRA image shows the right renal artery branching from the true lumen (arrow), and the left renal artery originating from the false lumen (arrowhead).
D: An oblique axial MPR image shows the celiac artery branching from the small true lumen (arrowhead).
E: An oblique axial MPR image shows the superior mesenteric artery branching from the small true lumen (arrowhead).
T: true lumen, F: false lumen
dynamics in aortic aneurysm and dissection. Spatial resolution is sacrificed because greater importance is focused on temporal resolution, but an acquisition technique with superior spatial as well as temporal resolutions, called time-resolved imaging of contrast kinetics (TRICKS), has recently emerged (Fig. 4).

MRA Topics

1. Parallel imaging

This is an image acquisition method using multiple coils called SENSE, ASSET, PAT, or SPEEDER. Theoretically, the acquisition time can be shortened to ‘1/number of coils.’ It is also applicable to any pulse sequence, and the current acquisition method may be modified and used. This method can be employed to not only shorten the acquisition time but improve spatial resolution (Fig. 5).

2. Diagnosis of the artery of Adamkiewicz

The depiction of the artery of Adamkiewicz is important for the operation of the thoracic descending aorta. In the graft replacement of the thoracic descending aorta for thoracic aortic aneurysm, reconstruction of some intercostal arteries are generally performed to preserve blood flow of the spinal cord. The artery of Adamkiewicz supplying the spinal cord originates from the intercostal or lumbar artery, and the branching level varies among individuals. Usually, the artery branches at a level...
between the 7th intercostal artery and 2nd lumbar artery, from one of these arteries. In preoperative identification of the intercostal (lumbar) artery, branching the artery of Adamkiewicz may contribute to preventing postoperative paraplegia due to spinal cord ischemia.

To visualize the artery of Adamkiewicz by MRA, there are techniques employing the time-resolved method\(^7\)\(^8\) and the slow infusion (Fig. 6) method\(^9\)\(^10\). To identify the artery of Adamkiewicz by MRA, it is important to differentiate the artery from the anterior radiculomedullary vein, because both vessels show a characteristic ‘hairpin turn’ configuration. The time-resolved method demonstrates the artery of Adamkiewicz by sequentially obtaining the arterial to venous phase images utilizing high temporal resolution. The slow infusion method shows the artery of Adamkiewicz by demonstrating the continuity from the aorta to the intercostal artery, the artery of Adamkiewicz, and to the anterior spinal artery utilizing the high spatial resolution. The detection rates employing the former and latter methods were reported to be 69–84\(^%\)\(^7\)\(^8\) and 57–80\(^%\)\(^9\)\(^10\), respectively.

Attempts to diagnose the artery of Adamkiewicz using MDCT have also been reported. Differentiation of the artery of Adamkiewicz from the anterior radiculomedullary vein is also important for diagnosis using MDCT. Generally, MDCT shows the artery of Adamkiewicz by demonstrating the continuity from the aorta to the intercostal artery, the artery of Adamkiewicz, and to the anterior spinal artery, similarly to the slow infusion MRA method. The detection rate of the artery of Adamkiewicz CTA was reported to be 29–60\(^%\), lower than that on MRA\(^9\)\(^10\). Particularly, the detection rate in patients with dissecting aortic aneurysm is higher by MRA than by CTA. In our experience, the detection rates on CTA and MRA were 58 and 92\(^%\), respectively, showing a markedly higher rate on MRA\(^10\).

3. Non-contrast MRA

The new non-contrast MRA technique, such as the
time-spatial spin labeling pulse (Time-SLIP) and fresh blood imaging (FBI), has been attracting attention because accurate diagnoses comparable to those made by contrast enhanced MRA are expected, and their usefulness in peripheral artery disease and renal artery disease has been reported.\textsuperscript{(12)}

Nephrogenic systemic fibrosis (NSF) associated with contrast medium (gadolinimum) in patients with renal dysfunction has recently been warned.\textsuperscript{(13)} Usually, patients with arteriosclerotic diseases, such as aortic aneurysm, may have renal dysfunction, for whom future advancement in non-contrast MRA is anticipated.

\textbf{MRA AND CTA}

MRA is superior to CTA regarding the following points: 1) No radiation exposure, 2) the incidence of adverse effects of contrast medium is low, and 3) easy image post processing because structures other than vessels are not visualized. However, it also has disadvantages compared to CTA, such as: 1) low spatial resolution and 2) less sensitive to calcification.

Based on these characteristics, MRI (MRA) is recommended for babies and children requiring the avoidance of irradiation, young patients who need long-term and repeated image diagnosis for aortic dissection or aortic aneurysm, and patients allergic to iodine contrast medium.

\textbf{CONCLUSION}

Diagnoses of aortic diseases by MRI, mainly MRA, were described. There are various acquisition techniques for MRA, proving extensive information, but the selection of an appropriate method for diseases and pathologies, including MDCT, is important.

\textbf{REFERENCES}