Magnetic resonance angiography

C.J.G. Bakker

Department of Radiology, University Hospital Utrecht, Heidelberglaan 100, NL-3584 CX Utrecht, The Netherlands

The sensitivity of magnetic resonance to microscopic and macroscopic flow phenomena was recognized in the early 1950s. The advent of magnetic resonance imaging (MRI) has given a strong impetus to magnetic resonance flow studies, first, because flow generates artifacts in the images and, second, because flow acts as an inherent source of contrast in MRI. MRI thus offers the potential for noninvasive, nondisturbing studies of the structure and function of the vascular system [1–5].

In the past decade numerous methods have been devised to sensitize MRI to flow. The resultant techniques – collectively referred to as magnetic resonance angiography (MRA) – can be divided into methods directed at the depiction of vascular morphology and methods directed at obtaining functional information. By now both have become available on most commercial magnetic resonance scanners, and initial results have been obtained throughout the human vascular system.

Current MRA practice is governed by two approaches: time-of-flight and phase-contrast angiography. *Time-of-flight*, or inflow, MRA is based on the signal enhancement which arises from inflow of fully magnetized spins in an otherwise saturated slice or volume. In principle both venous and arterial blood exhibit this inflow effect. Enhancement from venous or arterial flow can be suppressed by selective presaturation. Deliberate choice of regions to be saturated thus offers possibilities for selective angiography, for example for tracing the areas which are fed by certain vessels or tracking down the feeding vessels of vascular malformations. *Phase contrast* MRA is a subtraction technique in which magnetic field gradients are applied to create a velocity-dependent phase shift between flowing and stationary spins. A phase-contrast magnetic resonance angiogram is obtained by subtraction of two source images with different velocity sensitivity but identical sensitivity for stationary tissue. Phase-contrast angiograms in principle give information on the direction and velocity of the flow. Compared to time-of-flight MRA, phase-contrast MRA is more sensitive to slow flow and offers better background suppression. On the

other hand, phase-contrast MRA is more time consuming than time-of-flight MRA and puts higher demands on the equipment.

Both time-of-flight and phase-contrast MRA can be performed in a two- or a three-dimensional acquisition mode. Three-dimensional techniques generally offer a better signal-to-noise ratio, higher resolution, and better coverage but are relatively sensitive to gross motion during acquisition (respiration, peristaltic movements etc.) and less sensitive to slow flow. Both two- and three-dimensional acquisitions produce a set of slices through the volume of interest in which blood vessels represent the highest signal magnitude, and static tissue is suppressed (Fig. 1a). The obvious way in which to evaluate this dataset is sequential observation of individual slices. A better visualization of spatial structures is obtained by subjecting the dataset to the maximum intensity projection algorithm (Fig. 1b). This algorithm generates a set of arbitrarily oriented projections through the volume of interest which – when displayed as a movie – provide a three-dimensional view of the vasculature.

In the past few years the number of studies in which the value of MRA was compared to that of conventional techniques for carefully selected pa-

Fig. 1. Two-dimensional time-of-flight study of the carotid arteries of a healthy volunteer (64 slices, thickness 3 mm, overlap 1 mm, cranial presaturation). *Left*, axial source image; *right*, lateral projection angiogram

Fig. 2. Coronal maximum intensity projection of a three-dimensional phase-contrast study of a patient with an arteriovenous malformation of the left temporal lobe

tient populations has increased rapidly. Yet it would be premature to draw conclusions as to the clinical utility of MRA since the technique is still in a developmental stage. Faster scan techniques, more effective suppression of stationary tissues, dedicated excitation and receiver coils, more specific contrast agents, and better reconstruction and display algorithms are among the areas in which improvements are to be anticipated.

So far, the potential of MRA has been demonstrated most convincingly in the intra- and extracranial circulation. In this area a certain consensus has been reached with regard to the optimum (combination of) scan techniques. Tentative applications include the demonstration and follow-up after treatment of arteriovenous malformations (Fig. 2), aneurysms, atherosclerotic plaques, tumors, and thrombosis of the major venous sinuses. With regard to extracranial MRA, ultrasound methods often constitute an attractive alternative. It appears likely that a combination of MRA and duplex sonography will eventually replace conventional angiography in this region, particularly in patients with disease of the carotid bifurcation.

In contrast to the successful application of MRA in the intra- and extracranial circulation, MRA hitherto has produced rather disappointing results in examinations of the aorta, vena porta, and renal and coronary arteries. Respiration and movement artifacts are the main malefactors here. There is a hope that faster imaging techniques and artifact reduction methods will offer solace in the

Fig. 3. Digital subtraction angiogram (*left*) and corresponding magnetic resonance angiogram (*right*) of a patient with a severe stenosis of the internal carotid artery. The magnetic resonance angiogram overestimates the stenosis due to turbulence-induced signal losses (two-dimensional time-of-flight, 64 slices, thickness 3 mm, overlap 1 mm, cranial presaturation)

near future. In patients with suspected venous thrombosis in the chest, abdomen, and pelvis, MRA has gradually evolved into a valuable adjunct to duplex sonography and computed tomography.

For the peripheral circulation, the efficacy of MRA is still severely limited by its relatively small field of view and therefore unacceptably long scan times.

In its current state of development, the clinical utility of MRA is hampered by some persistent artifacts and pitfalls. A major problem is constituted by signal losses due to saturation (slow or stagnant flow) and intravoxel dephasing (complex flow and magnetic susceptibility variations). In practice this might lead to false-positive diagnoses or overestimation of the degree of stenosis in diseased vessels (Fig. 3). Not surprisingly, a large proportion of current research effort is devoted to hardware and software modifications which reduce the sensitivity of MRA to complex flow.

Notwithstanding these and other shortcomings of present-day MRA, continued research efforts and clinical testing are expected to make MRA a viable means of performing angiography in most patients in the next few years.

References

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Book Review

Publishers are requested to contact the editorial office *before* sending copies of books for review. If desired, a review copy can then be ordered. We cannot guarantee that unsolicited review copies will be returned.

P. Buchmann, W. Brühlmann: **Investigation of anorectal functional disorders**. Springer, Berlin Heidelberg New York, 1993. 212 Pages, 130 Figures, 38 Tables. Hardcover, DM 248,00 (ISBN 3-540-55326-6)

The monograph contains 20 different articles by 14 authors. Kamm reports on the physiology and pathophysiology of defaecation. Citing many references, he comes to the conclusion that control of the large bowel and sphincter function are not yet completely understood. Hildebrandt's article on ultrasound anatomy of the pelvic floor confirms our knowledge about this region in the living subject.

The article by Buchmann about clinical examination is very important, but we do not agree that sigmoidoscopy is rarely possible without an enema, since the rectum is empty most of the time. The pages following describe the technique of defaecography, the indications and the value for treatment decisions.

Stuckmann compares conventional radiography with CT and MR. Marti follows with balloon proctography, Erkenbrecht with endoscopy, Kamm with scintigraphy and Kuijpers with transit time measurement. Very interesting and unexpected is the finding that half of the patients complaining of constipation have a normal transit time! After the short article on manometry, electromyography and other functional pelvic floor tests by Kamm follows no. 15, rectal prolapse by Mathieu. Kuijpers provides the surgeon's viewpoint; he believes that denervation of the pelvic floor leads to impaired function from enteroceles up to total rectal prolapse. Rectal outpocketing by Hauck is a very interesting feature, as demonstrated by defaecography, but we doubt the existence of real hernias in holes of the levator muscles; additionally, small enteroceles are not pathological features. The assessment of functional constipation by Kuijpers, defaecography and incontinence by Marti, and anal malformation conclude the monograph.

The reader will find many questions in this book and will receive much incentive to distinguish real diseases from so many harmless deviations. The newest references after each contribution will be particularly helpful.

F. Stelzner (Bonn)