MR Perfusion Imaging

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During the last 10 years, a variety of MR techniques have been developed that can provide images of cerebral perfusion (1). These approaches include those that require the injection of paramagnetic contrast agents (bolus-tracking approaches) as well as those that magnetically tag water in arterial blood as it moves into the brain. The effects of “tagged” arterial water on brain MR images can be used to calculate quantitative CBF images that can be expressed in classical physiologic units (ie, cc/100 g/min). The major drawback to these tagging techniques is that, with the current technology, they are rather insensitive and require relatively long imaging times (=10 minutes). Given this restriction, it is unlikely that MR arterial spin-tagging approaches will be applied to the clinical evaluation of acute stroke in the near future. Nevertheless, they could play an important role in the clinical evaluation of cerebrovascular diseases that provide a longer diagnostic “window,” especially for those that require absolute quantitation.

Following the quantitative CBF response to cerebrovascular challenges is one scenario in which MR spin-tagging flow approaches could be very useful. Samuels et al (2) employed the MR spin-tagging response to acetazolamide challenge to study middle cerebral artery stenosis, and used the results to characterize specific patterns of impaired perfusion. In this issue of the AJNR, Kastrup et al (page 1233) suggest the use of MR arterial spin-tagging approaches with another variant of the cerebrovascular challenge—breath-holding. Kastrup and colleagues demonstrate that breath-holding can provide reproducible changes in CBF in control subjects that can be followed accurately, both regionally and globally, using MR spin-tagging techniques. The advantage of the breath-hold approach is that it obviates the need for acetazolamide injection or CO₂ inhalation; the disadvantage is that it cannot be used for patients with impaired respiratory function. Both Samuels et al and Kastrup et al underscore the importance of obtaining ancillary data (eg, T₁ relaxation time images) to enable MR spin-tagging data to be interpreted in terms of absolute CBF values. This ability to quantify CBF absolutely is potentially of great clinical importance.

Functional MR (fMR) imaging approaches using blood oxygen level dependent (BOLD) effects also have been used to follow the response to cerebrovascular challenges. BOLD approaches are more sensitive than MR spin-tagging approaches. Kastrup et al emphasize, however, that BOLD results are harder to interpret because fMR imaging responds to changes in various physiologic parameters (eg, CBF, cerebral blood volume, and cerebral oxygen consumption), whereas MR spin-tagging responds primarily to changes in CBF. Nevertheless, MR arterial spin-tagging approaches also present problems in quantitation of CBF. For example, calculated CBF values will be artificially low when arterial transit times are abnormally long, which might occur in compromised brain regions that have extensive collateral circulation. This issue could be examined using MR bolus-tracking approaches (1), which can give information on arterial transit times in compromised brain areas. Further validation of the quantitative ability of the arterial spin-tagging technique is needed before the results can be applied to individual patients.

The results of Kastrup et al and Samuels et al demonstrate the usefulness of MR arterial spin-tagging approaches for studies of cerebrovascular reserve. These approaches have a number of advantages over other techniques (eg, PET, SPECT, CT, etc); they are noninvasive, easily repeatable, and have relatively good spatial resolution. In the near future, a number of technical advances, such as phased-array head coils and higher magnetic field strengths, undoubtedly will increase the sensitivity of MR arterial spin-tagging approaches, and could make them viable for routine clinical studies of cerebrovascular disease.

An interesting sideline to these studies of physiologic perturbations of CBF is the subtlety and
possible pervasiveness of the effects. Although a
gross respiratory change such as a 30-second
breath-hold would be unlikely to occur during a
conventional fMR imaging experiment, more sub-
tle respiratory changes could accompany some ac-
tivation paradigms, particularly those with “sur-
prise” components. This could result in MR signal
changes secondary to the unanticipated respiratory
(or cardiac) responses. Statistical analysis might
classify erroneously respiratory responses as
noise, false localization of a cognitive task, or a
true but secondary phenomenon. The latter pos-
sibility reemphasizes the complexity, as well as the
richness, of these new functional imaging

techniques.

Imaging Brain Abscesses with Diffusion-Weighted and Other Sequences

With so many pulse sequences now available to
image the brain, one has to reflect on what is the
most practical way of deriving maximal informa-
tion in a clinically acceptable period of time. The
use of MR imaging keeps expanding, not only pro-
viding images of incredible detail but allowing the
study of metabolism and physiology. As a result,
one could spend hours just studying a single
patient.

Diffusion-weighted imaging has been used for
evaluation of stroke, tumors, demyelination, and
vertebral body compression fractures. It is only log-
ical to attempt to extend its use to patients with
brain abscess. If one only uses single-axis diffu-
sion-weighted imaging and one B value, there is no
significant time penalty. Nevertheless, many now
believe that diffusion-weighted imaging should be
obtained in three axes (Iz, Ix, and Iy) and then post-
processed as an expression of its natural logarithm
(trace imaging) to reduce the contribution of T2
signal “shine through.” In addition, apparent dif-
sion coefficient (ADC) maps are needed for stan-
dardization of the data and for obtaining quantita-
tive information from diffusion-weighted images.
ADC maps ideally are produced by using more
than two B values. Because these manipulations in-
crease imaging time and generally need off-line
post-processing, the question is, when should we
use diffusion-weighted imaging? The answer is not
simple because diffusion-weighted imaging inno-
vations are constantly discovered.

In this issue of the AJNR, Desprechins and col-
leagues (page 1252) describe the use of diffusion-
weighted imaging for characterization of nonspe-
cific ring-enhancing lesions that proved to be
abscesses. Although only three patients were stud-
ied, their results are impressive. The necrosis with-
in the lesions showed increased signal intensity on
diffusion-weighted images and a markedly de-
creased signal on ADC maps. In similar and recent
publications, two different groups of investigators
found identical results in a total of six patients (1,
2). Contamination by signal from surrounding ede-
ma is not a problem, but abscesses appear slightly
larger on diffusion-weighted images than on con-
ventional MR images. This probably represents a
summation of the necrotic region and the capsule.
Although the capsule of an abscess is generally hy-
pointense on T2-weighted images (assumed to be
related to presence of free radicals), the capsule is
hyperintense on diffusion-weighted images. The
reason for the lack of susceptibility effects from the
capsule, leading to signal loss on diffusion-weight-
ed images, is not known. On diffusion-weighted
images, the hyperintensity seen in the necrosis
probably is related to a restriction of microscopic
movement of water molecules as they are contained
inside a complex matrix of proteins, inflammatory
cells, cellular debris, and bacteria in high-viscosity
pus. Additionally, water molecules in abscesses are
bound to carboxyl, hydroxyl, and amino groups on
surfaces of macromolecules. This also limits their
translational movement. This finding was con-

cirmed using ADC maps and thus hyperintense
“shine through” from T2 relaxation effects does
not contribute significantly to the appearance of ne-
crosis on diffusion-weighted images. When ADC
maps were generated, a marked reduction in the
ADC related to restricted Brownian motion of free
water was shown. In contradiction to the utility of
diffusion-weighted imaging in the diagnosis of ce-
bral abscesses, Krabbe at al evaluated one ab-

sciss that showed low signal on diffusion-weighted
images and increased ADC. Desprechins et al at
tribute the finding to the technique used, question-
ning the reported findings. High-grade astrocytomas
show low signal on diffusion-weighted images and
high ADCs. This is probably because the water
molecules in these tumors are allowed a greater de-
gree of freedom in their motion. The so-called ne-
crotic center of a tumor contains a less viscous ma-
terial composed by less cellular debris and fewer
inflammatory cells as well as a more serous fluid
(often hemorrhagic). Thus, water molecules are

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