Diffusion-Weighted MRI in Acute Subcortical Infarction

Michael B. Singer, MD; June Chong, MD; Dongfeng Lu, PhD; Wouter J. Schonewille, MD; Stanley Tuhrim, MD; Scott W. Atlas, MD

Background and Purpose—Conventional imaging lacks sensitivity and specificity for the detection of early subcortical cerebral infarction. The purposes of our study were (1) to determine the accuracy of diffusion-weighted (DW) MRI for early subcortical infarction and (2) to determine the efficacy of DW MRI for differentiating acute from nonacute subcortical infarctions when conventional MR demonstrates multiple infarctions.

Methods—Thirty-nine patients with clinically diagnosed acute subcortical infarction and 17 control subjects were imaged with both conventional and DW MRI from 7 hours to 4 days (mean, 2.0 days) after onset of symptoms. All images were read blinded to specific clinical findings. In all cases, the precise neuroanatomic locations of lesions were noted. These lesions were subsequently correlated by an experienced stroke neurologist to determine whether their locations correlated to the patients’ symptoms.

Results—the accuracy of DW MRI for acute subcortical infarction was 94.6%. In 4 of 39 cases, the acute infarction was not detected on conventional MRI. In 24 of 39 cases, conventional MRI showed the acute lesion as well as multiple other subcortical lesions. In each of these 24 cases, the DW MRI showed a single lesion to be acute, and in all 24 cases, that lesion corresponded to the patients’ acute symptoms.

Conclusions—DW MRI has very high accuracy for acute subcortical infarction and can differentiate acute from nonacute lesions. These data have significant implications in guiding patient management and patient selection for clinical trials.

Key Words: cerebral infarction ■ diagnostic imaging ■ magnetic resonance imaging ■ stroke, acute
artifact (ie, typically seen near interfaces between brain and air-filled paranasal sinuses). The lesion did not necessarily have to be present on more than one of the three single-axis DW images to be interpreted as an infarction (ie, obscuration of stroke-related hyperintensity situated within normal internal capsule hyperintense signal on one diffusion axis might be eliminated by changing the direction of diffusion sensitivity, making these anisotropic effects less problematic). In all cases, the precise neuroanatomic locations of such lesions were noted. These lesions were subsequently correlated in consultation with an experienced stroke neurologist, who had personally examined the patients before the MRI study, to determine whether the locations of high intensity on DW MR correlated to all or part of the patients’ symptoms. On FSE images, all focal hyperintense abnormalities in deep and subcortical neuroanatomic locations were noted.

Results

Thirty-seven of the 39 patients with the clinical diagnosis of acute subcortical infarction had focal areas of high intensity on DW MR that correlated with all or part of the patients’ clinical symptoms. Of the two patients with acute subcortical infarction and negative DW MRI, one was imaged within 34 hours and the other within 72 hours of ictus. In 1 of the 17 control patients, an acute focal subcortical infarction was identified on DW MRI. Overall, the sensitivity of DW MR for acute subcortical infarction was 94.9%, specificity was 94.1%, positive predictive value was 97.4%, and negative predictive value was 88.9%. The accuracy of DW MRI for acute subcortical infarction was 94.6% (Table).

In 4 of 39 cases, the acute infarction (ie, the hyperintense lesion on DW MR) was not detected on FSE images. Two of these were imaged in less than 12 hours after onset of symptoms. In 24 of 39 cases, FSE images showed the acute lesion as well as multiple other subcortical lesions that were indistinguishable from each other. In each of these 24 cases, the DW MR showed a single lesion to be acute, and in all 24 cases, that lesion corresponded to the patients’ acute symptoms (Figure). In these 24 cases, 11 were imaged within 48 hours and 14 were imaged between 56 and 96 hours.

In 1 case DW MR demonstrated additional acute lesions that did not correlate with clinically apparent deficits but were subsequently shown to be clinically relevant and likely due to an acute ischemic insult.

Discussion

DW MRI is a technique that is exquisitely sensitive to the net translational movement of water molecules. When placed into a strong magnetic field gradient, translational movement of water protons results in a phase shift that can be detected as relative signal loss compared with regions of reduced water motion. Preliminary studies using DW MRI have indicated that early infarction is demonstrated as regional high signal intensity compared with background tissue. This relative hyperintensity presumably reflects restriction of tissue water movement in the area of infarction, although the precise pathophysiological events underlying the change in water diffusion are unclear. It is thought that the loss of normal homeostasis and cell membrane function within ischemic cells leads to increased cell membrane permeability. The secondary shift of water from the extracellular space, where diffusion is nearly unrestricted, to the intracellular compartment, where there is apparently a more restricted environment for water

Selected Abbreviations and Acronyms

- DW = diffusion weighted
- FSE = fast spin-echo
- TE = echo time
- TR = repetition time

Summary of Results: DW MRI for Acute Subcortical Infarction in 39 Patients

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<tr>
<td>Sensitivity</td>
<td>94.9%</td>
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<tr>
<td>Specificity</td>
<td>94.1%</td>
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<tr>
<td>Positive predictve value</td>
<td>97.4%</td>
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<tr>
<td>Negative predictve value</td>
<td>88.9%</td>
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<tr>
<td>Accuracy</td>
<td>94.6%</td>
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Our data also demonstrate that abnormal foci in the subcortical gray and white matter can be identified on DW MRI in regions that do not correspond to clinically apparent neurological deficits. It is possible that these are false-positive findings that do not represent cerebral lesions, but it is more likely that these are acute infarctions that fail to produce recognized symptoms ("silent" infarctions). Indeed, silent infarctions are reportedly present on CT scans of between 10% and 30% of patients with cerebrovascular disease and are usually small, subcortical lesions. It is therefore not unlikely that the foci of hyperintensity on DW MRI (ie, restricted diffusion) without clinical correlation do indeed represent infarctions.

The recent development of thrombolytic and neuroprotective agents has further raised the significance of accurate detection of acute infarction to new levels, since the real possibility of early intervention to limit the extent of damage from the ischemic event exists. However, since the therapy is not without significant risk, it is important to distinguish patients who have evidence of new ischemic damage from those who have (re)emergence of signs and symptoms from preexisting lesions, perhaps due to unrelated intercurrent infections or metabolic derangement. Because it is precisely those patients with small subcortical infarctions who are most likely to have multiple lesions, many of which may be silent, DW MRI appears to hold important promise for aiding the clinician in making distinctions that are difficult on clinical grounds alone. Since most acute interventional trials are currently limited to patients who can be treated within 6 hours of symptom onset, it remains to be demonstrated that our findings can be extended to that time window. However, previous work suggests that DW abnormalities appear very shortly after the onset of ischemia.

The technique of DW MRI is readily performed in patients who cannot otherwise cooperate for conventional MRI, since in the echo-planar implementation image acquisition occurs in subsecond time frames, making this technique particularly attractive as an option in very ill patients. Moreover, the accurate diagnosis of acute infarction by such a rapid imaging method is also appropriate for subjects entering therapeutic trials, where time is of the essence in patient management and triage. It is as yet uncertain whether DW MRI offers a method for distinguishing patients who have reversible (or at least potentially treatable) lesions from those who do not.

Conclusion

DW MR, without the use of quantitative diffusion coefficient maps, has very high sensitivity, specificity, and accuracy for acute subcortical infarction and can differentiate acute from nonacute lesions. DW MR can also reveal additional "acute lesions" in these patients, which either represent additional clinically silent acute infarctions or represent false-positive findings. These data have significant implications in guiding patient management and patient selection for clinical trials.

References


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