A Standardized MRI Stroke Protocol
Comparison with CT in Hyperacute Intracerebral Hemorrhage

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Background and Purpose—Diagnostic imaging in hyperacute ischemic stroke has been revolutionized by the introduction of diffusion- and perfusion-weighted MRI (DWI and PWI). CT, however, is still needed to exclude intracerebral hemorrhage (ICH). The purpose of our study was to determine the diagnostic accuracy of a standardized, multimodal MRI (mMRI) stroke protocol in the qualitative and quantitative assessment of hyperacute ICH (<6 hours).

Methods—We investigated 9 patients with hyperacute ICH with CT followed immediately by a standardized mMRI stroke protocol (DWI, PWI [T2*-WI], FLAIR, T2-WI, and MRA). The time interval between MRI and symptom onset ranged from 3 hours to 5 hours 45 minutes. We analyzed and compared the size of the hematoma on CT and all mMRI images by semiautomatic volumetry.

Results—ICH was unambiguously identified on the basis of all mMRI sequences. With increasing susceptibility effect (T2*-WI), the ICH, appearing as an area of hyperintensity with central signal loss, became qualitatively most evident. Regarding quantitation, T2*-WI overestimated (median and mean difference, 18.9%/17.8%; SD σ=24.4%) and DWI correlated best (median and mean difference, 3.97%/−4.36%; SD σ=37.42%) with hematoma size on CT.

Conclusions—Multimodal stroke MRI is as reliable as CT in the assessment of hyperacute ICH. Therefore, additional CT is no longer necessary to rule out ICH in hyperacute stroke. The use of mMRI alone in the diagnostic workup of a hyperacute stroke patient saves time and costs while rendering all the critical information needed to initiate an optimal treatment. (Stroke. 1999;30:765-768.)

Key Words: intracerebral hemorrhage ■ magnetic resonance imaging ■ stroke ■ tomography, x-ray computed
All patients were examined with a fourth-generation CT scanner (PQ 2000, Picker) and immediately thereafter with a 1.5-T whole-body MR imager (EDGE, Picker) equipped with enhanced gradient hardware for echo planar imaging (EPI). For the MRI examination we used a circular polarized head coil. The mMRI protocol includes an axial T2-W fast-spin-echo sequence, an axial fluid-attenuated inversion recovery (FLAIR) EPI sequence, an axial isotropic DWI SE EPI sequence, time-of-flight MR angiography, and PWI with an axial T2*-W gradient echo EPI sequence (40 data sets during and after injection of 25 mL Gd-DTPA (Magnevist, Schering AG) with a power injector (5 mL/s).

The diagnosis of ICH was established by CT. The acute hematoma was identified on MRI on the basis of a heterogeneous region of signal loss and focal hyperintensity characteristic of the MR appearance of ICH. To evaluate the sensitivity of different MRI sequences, we compared the hematoma size in CT and MRI images by performing an offline volumetric analysis of the hematoma on CT images, FLAIR images, fast-spin-echo T2-WI, DWI source images (b ≥ 1000), and PWI source images. The area suspected as representing the hematoma was traced by hand with the aid of an image analysis system (VISTAR and VOXEL, Picker) for each slice separately, and these areas were subsequently used to calculate lesion volumes. Mean, median, and SD are expressed in relation to hematoma size on CT, ie, a negative sign stands for a larger hematoma volume on MRI than on CT.

Results

Intracranial hemorrhage was qualitatively detected on all CT and all MRI images (fast T2, FLAIR, DWI, and T2*-WI) in all 9 patients. The mean time between CT examination and symptom onset was 2 hours (range, 0:45 to 3:45), and the mean time between MRI and symptom onset was 4 hours (range, 3:00 to 5:45), which leaves a mean time interval between CT and MRI of 2 hours (range, 1:00 to 3:45). The scanning time for the entire MRI protocol was approximately 20 minutes with an additional 10 minutes for patient positioning. The typical appearance of ICH on the MRI images was a heterogeneous focus of high and low signal intensities. With increasing susceptibility weight, the central area of hypointensity became more pronounced. The T2*-WI showed no or only few areas of hyperintensity, or merely a faint ring around a central core of signal loss. Figures 1 and 2 illustrate the appearance of a larger and a smaller hyperacute ICH on CT and MRI in 2 representative patients; these findings were common to all 9 patients.

Volumetric analysis showed a good raw correlation of hematoma volumes in all MRI images compared with CT. As already reported by Rosen et al., images obtained with sequences with a high sensitivity for susceptibility effects (T2*-WI, FLAIR) generally overestimate the actual hematoma size in comparison to the lesion volume assessed on CT. Hematoma volumes on DWI (median and mean difference, 3.97%/−4.36%; SD σ = 37.42%) followed by FLAIR (median and mean difference, −2.91%/−6.25%; SD σ = 28.39%) corresponded best with lesion size on CT. Conventional T2-WI substantially underestimated (median and mean dif-
ference, 17.24%/12.98%; SD σ=34.46%) and T2*-WI substantially overestimated (median and mean difference, –17.94%/-18.86%; SD σ=24.45%) the hematoma size (see the Table).

**Discussion**

Our MRI findings in 9 patients with primary hypertensive ICH examined within 6 hours of symptom onset clearly demonstrate the sensitivity of susceptibility-weighted MRI sequences for fresh intracerebral blood. MRI performed with a standardized multimodal protocol for stroke as also used by others,15,16,18 therefore, is as good as CT in ruling out or defining the extent of ICH. Older studies postulated a 24-hour gap before detectable amounts of paramagnetic deoxyhemoglobin have accumulated.7,9 Our results, however, support the hypothesis that small amounts of deoxyhemoglobin are present within the very first hours of ICH and are detectable by susceptibility-weighted MRI sequences. Figures 1 and 2 suggest that T2*-WI are suited best for the diagnosis of ICH, which holds true for the qualitative detection also of relatively small thalamic hematomas without mass effect (Figure 2). For quantitative analysis, DWI and FLAIR are the best indicators of lesion volume compared with CT. Further information, such as the presence of space-occupying edema, midline shift, and ventricular hemorrhage, is best derived from conventional T2-WI. In addition to the standardized stroke protocol, postcontrast T1-WI scans may be obtained after PWI if another primary disease is suspected (eg, apoplectic glioma or metastases). There currently is no information about the sensitivity of stroke MRI for subarachnoid hemorrhage (SAH) in patients. Animal experiments21 demonstrated early DWI changes in rats suggesting early vasospasm, and spreading depression as indirect signs of SAH. A signal loss due to susceptibility effects analogous to ICH is not described. Although strokelike symptoms are unusual in SAH, further studies aimed at the diagnostic reach of stroke MRI in acute SAH are worthwhile.

Patel et al in 199611 reported a case cohort of 6 patients evaluated with MRI within 6 hours after acute ICH and also found susceptibility-weighted sequences to be sensitive for acute ICH. In their patient series, however, CT was performed from 9.5 hours up to 4 days after symptom onset, so that secondary hemorrhage after primary ischemia cannot be excluded. In 3 patients no time interval for CT was given. Furthermore, MRI examinations were conducted with 3 different types of MR scanners (with different field strengths), and volumetric analysis was not performed.

In the emergency evaluation of acute stroke, “time is brain.”22 It is thus of utmost importance that diagnostic efforts are as specific and time efficacious as possible, especially when considering aggressive treatment strategies such as thrombolysis.23,24 MRI stroke protocols, including DWI and PWI, are very promising with regard to the characterization of acute stroke patients and the identification of patients.
suitable for specific therapy. Surprisingly, though, MRI is still not generally considered to be the primary and only diagnostic tool in acute stroke patients, because there is doubt regarding the ability to detect hyperacute hemorrhage. Although a larger number of patients would be useful to confirm these findings, our results show that mMRI is as sensitive as CT in the diagnosis of ICH. The initial and exclusive use of these findings, our results show that mMRI is as sensitive as CT in the diagnosis of ICH. The initial and exclusive use of mMRI is therefore feasible, cost-effective, and time saving.

In conclusion, mMRI is the single diagnostic tool of choice in the initial assessment of patients with hyperacute hemorrhagic stroke.

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References


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