Diffusion and Perfusion MR Imaging in the Evaluation of Ischemic Stroke During the First Week


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Introduction
A number of studies of diffusion weighted magnetic resonance imaging (DWI) on patients suffering from acute ischemic stroke has been published (1,2,3). Areas of impaired diffusion seem to indicate ischemic damage. Repeated measurement of this area and apparent diffusion coefficient (ADC) on different time points gives information about the time course of ischemic changes. Sørensen et al (4) and Baird et al (5) combined DWI and magnetic resonance perfusion imaging (PI) in acute stroke patients. Their results suggest that by combining these two methods, one could be able to characterise the ischemic penumbra. The purpose of the present study was to compare the DWI and PI in acute ischemic stroke and to study the time course of ischemic lesion.

Patients and methods

Patients. 20 patients (9 male, 11 female; age range 56-89 yrs, mean 72.5 yrs) suffering clinically from acute (<24 hrs) ischemic stroke were enrolled into the study after hemorrhagia had been excluded by head CT. Written consent for the study was given by the patient or an accompanying family member. The study was approved by the ethics committee at our institution.

Magnetic Resonance Imaging. The study protocol included three MR imaging sessions: 1) the first day (on which the patient came to the hospital), 2) the second day, 3) after one week (7th-9th day). The imaging was performed on a EPI capable 1.5 T Siemens Magnetom Vision scanner. The imaging protocol included diffusion weighted, conventional T2- and proton density-weighted images, 2D phase contrast angiography, perfusion imaging and pre- and post-contrast T-weighted imaging. Imaging was performed with a standard head coil total imaging time being about 20 min.

Diffusion weighted imaging. DWI was performed using a multi-slice, single-shot echo planar spin-echo sequence. Diffusion gradients were applied sequentially in three orthogonal directions to generate three images with diffusion sensitivity (b-value) of 0 mm²/s, 500 mm²/s and 1000 mm²/s. The sequence generated also images with b-value of 0 s/mm² at the same slice positions. A set of 19 slices was obtained covering the whole supratentorial brain slice thickness being 5 mm. Acquisition time was 20 s. In order to minimise the effects of diffusion anisotropy, an average of all three diffusion directions was calculated to give the trace of diffusion tensor (trace image). The calculation of apparent diffusion coefficient (ADC image) was done on a pixel-by-pixel basis and was based on the negative slope of line fitting the two points for b versus ln(SI), where SI is the signal intensity.

Perfusion imaging. Dynamic echo-planar spin-echo images were obtained in 7 slices at 1.5 s intervals for 60 s immediately after intravenous bolus injection of gadopentetate dimeglumine. A total dose of 0.2 mmol/kg was given at a speed of 5 ml/s using an MR-compatible power injector. The slice positions were identical with those seven DWI images that contained the maximum areas of impaired diffusion. Relative cerebral blood volume (rCBV) images were generated on a pixel-by-pixel basis by numerical integration of relative concentration δR3 for the firstpass bolus through the brain. The first and last point for the integration were determined experimentally. Time-to-peak (TP) images were created from the δR3 data.

Data analysis. Quantitative volumetric measurements were performed by drawing ROI’s on trace, rCBV and TP images. The ROI drawn on the trace image was transferred to ADC image to give the mean ADC value within this region. For comparison of diffusion and perfusion defects on the first day, the area of impaired diffusion was separately measured on the seven slices containing the volume with PI. After the first imaging, four patients had developed hemorrhagia, which was included in the volumetric measurements but excluded from the ADC measurements.

Results

The time from onset of symptoms to the 1st, 2nd and 3rd MRI was on average 9.6 hrs, 29.6 hrs and 167.1 hrs, respectively. 18 of 20 patients underwent all three imaging sessions, two patients died before the third imaging. The results from DWI during the week and PI on the first day are presented here.

Diffusion imaging. All 20 patients had areas of high signal intensity in the initial study indicating acute ischemic stroke. Total volumes of lesions ranged from 682 to 80810 cm³. In 17 out of 20 patients the volume of impaired diffusion increased between the first and the second day. The mean of the lesion volume was 33.7 cm³ (sd 33.6) on the first day and 57.2 cm³ (48.2) on the second day. After the week the mean volume of lesion was 67.7 cm³ (51.1). The mean ADC values were 6.32 (1.03) on the first day, 6.25 (1.31) on the second day and 6.98 (0.86) after a week (unit: 10⁻⁶ mm²/s).

Perfusion imaging. In the initial study the PI was successfully performed and analysed in 14 out of 20 patients. In 6 out of 14 patients the volume of hypoperfused tissue was greater than the volume of impaired diffusion. The mean volume of hypoperfused tissue in rCBV images was 36.3 cm³ (36.1) and the mean volume of impaired diffusion from the corresponding slices was 27.5 cm³ (30.0). In general, the volumes of abnormally perfused tissue measured from the TP images were greater than those obtained from the rCBV images.

Conclusion

On average, the volume of ischemic lesion increased between the first and the second day and a slight increase was seen between the second day and one week. The mean ADC values of the ischemic lesions were low on the first two days and after a week only slight change upwards could be seen. Within 24 hours from the onset of symptoms the volume of decreased perfusion were larger than the volume of impaired diffusion. The result of present study suggest that the combination of diffusion and perfusion MRI imaging provides an excellent tool to evaluate the acute phase of ischemic stroke and its time course during the first week.

References


Trace images (a) on the 1st day, (b) 2nd day, and (c) after one week. The patient was 73 yrs old female, who got hemiparesis of the left side 6 hrs before the examination. Area of impaired diffusion is seen in the territory of the right cerebral artery.