Quantitative analysis of T2 and diffusion weighted images in epilepsy patients with secondary generalized seizures

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Introduction

Mental deterioration is a frequent observation in chronic epilepsy patients with a high number of secondary generalized seizures accumulated during lifetime. Neuropsychological evaluation has generally revealed a decline in cognitive abilities in these patients [1]. This observation raises the question whether secondary generalized seizures are associated with micro-structural changes of the brain, particularly in the frontal lobe. To detect possible structural effects, we used T2 and diffusion weighted (DW) imaging, and developed a quantitative evaluation method based on histogram analysis.

Methods

Thirteen healthy volunteers (aged 23–57 years, median 26) and nine epilepsy patients with secondary generalized seizures (>25 seizures, primary focus: frontal left 2, frontal right 1, temporal left 4, temporal right 1, multiple 1, aged 23–55 years, median 40) were included. Whole cerebrum imaging was performed with a clinical 1.5 T MRI system (Philips Intera, Philips Medical Systems), which was equipped with a standard quadrupolar head receiver coil. The protocol included a dual-echo turbo spin echo sequence (TSE-Dual) [TR 5211 ms, TE 11.9 ms/80 ms, matrix 256×256, FOV 204×112 mm], and a DW multi-shot echo-planar imaging (EPI) sequence [EPI-factor 31, b-values 0/400/800/1200 s/mm^2, 3 orthogonal diffusion sensitizing directions, TR 2 cardiac cycles, TE 76 ms, matrix 128×128, FOV 230×230 mm]. All images were co-registrated and spatially normalized to Talairach space. A percentile volume CSF map was created by attributing pixels individually to a CSF percentage (λ_{CSF}) on a scale of 0-100 %, based on their T2 relaxation times calculated from the TSE-dual images. Tissue was segmented from CSF by incorporating the cut-off $\lambda_{CSF} \leq 10$ %. Maps of the apparent diffusion coefficient (ADC) were calculated by second order polynomial fitting of the relation between direction averaged logarithmic signal intensities and b-values. Histogram analysis was performed on the T2- and ADC-maps, in the frontal and temporal lobe as well as the entire cerebrum. The histograms were fitted to the sum of two Gauss functions (each with an amplitude, width, and central position as parameters), and the parameters were statistically compared between volunteers and patients using a two-samples (two-tailed) Student's t-test.

Results

CSF-fractions were significantly ($p<0.05$) higher for the patients in all frontal areas, as well as in the left hemisphere and the entire cerebrum (see Table). In the averaged ADC-histograms, the peak height of the histogram was lower and the tail was slightly higher in the patient group (Figure 1). The histograms showed a shift towards higher ADC values, which was significantly reflected in the decreased amplitude of the first Gauss (in the left frontal lobe). Differences in histogram maximum were not significant. Histogram analysis on T2 maps data didn't yield significant differences. In figure 2, an example of an ADC-map of a volunteer and a patient is given.

Discussion

The quantitative DWI method showed subtle structural effects in epilepsy patients. This is the first study reporting that a long-term effect of secondary generalized seizures may be an increase in ADC. Structural effects were reflected by changes in the shape of the histograms, which showed a slight shift towards higher ADC-values. This increase in ADC and also the increase in λ_{CSF}, particularly in the frontal lobe, may explain the potential cognitive problems occurring in these patients in terms of neuronal damage. Since the effects were most evident in the left areas of the brain, the location of the primary focus might play a role. Further research is required to investigate whether the level of cognitive decline is related to the extent and the location of structural changes, and which other factors are involved.

		λ_{CSF} [%]		Amplitude first Gauss [%]	
		Patients	Volunteers	Patients	Volunteers
Frontal lobe	left	10.0 ± 6.5	5.1 ± 2.9 *	5.6 ± 0.7	6.4 ± 0.7 **
	right	8.5 ± 5.5	4.4 ± 2.6 *	5.7 ± 0.8	6.2 ± 0.7
	total	9.3 ± 5.5	4.8 ± 2.8 *	5.6 ± 0.7	6.2 ± 0.7
Temporal lobe	left	7.7 ± 6.8	4.2 ± 2.3	6.4 ± 1.2	7.0 ± 1.0
	right	3.5 ± 1.6	2.9 ± 1.8	7.0 ± 1.4	7.1 ± 0.7
	total	5.6 ± 3.3	3.6 ± 2.0	6.6 ± 1.0	6.9 ± 0.7
Entire cerebrum	left	8.3 ± 3.8	5.0 ± 2.4 *	5.7 ± 0.8	6.2 ± 0.7
	right	6.5 ± 3.4	4.5 ± 2.2	5.8 ± 0.9	6.1 ± 0.6
	total	7.4 ± 3.4	4.7 ± 2.3 *	5.7 ± 0.8	6.1 ± 0.6

*Table: Percentage CSF (λ_{CSF}) and amplitude of first Gauss peak in ADC-fits in different brain areas; notation: Mean **± SD;** * $p < 0.05$, ** $p<0.01$*

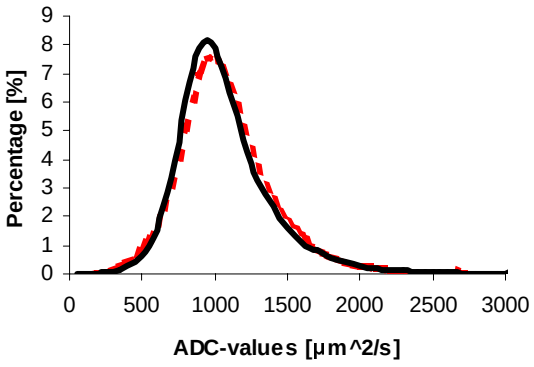

Figure 1 : Mean ADC histogram of the left frontal lobe of volunteers (black line) and patients (red dotted line)

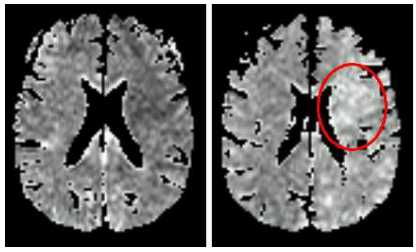

Figure 2: ADC-map of a volunteer (left) and a patient (right) with an hyperintense (encircled) area with high ADC-values

References: [1] - Dodrill CB. Epilepsia 1986;27:399-411.