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MRI Changes Associated with Partial Status Epilepticus

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Abstract: Neurological disorders of different etiology may cause identical clinical symptoms requiring additional diagnostic procedures for a precise differential diagnosis. Focal epileptic seizures have been shown to cause increased signal intensities in T2 and diffusion-weighted magnetic resonance images (MRI), mimicking other neurological disorders or diseases such as viral encephalitis. In some cases even the combination of neuroimaging and cerebrospinal fluid (CSF) analysis is not sufficient to obtain the final diagnosis, since epileptic seizures may cause pleocytosis as well. Some epilepsy centers presented cases of focal status epilepticus with severe but reversible MRI changes.

These cases indicate that MRI-changes following focal seizures are reversible over a different time window compared to MRI changes associated with other etiologies, such as viral infection. This data further suggest that in cases where focal seizures can not be ruled out, a follow-up MRI scan within a few days following the onset of symptoms significantly improves the precision of the differential diagnosis. Recently new scientific data were reported in this review.

Key words: Partial status epilepticus – Magnetic resonance imaging – Signal abnormalities

Introduction

A complex partial status epilepticus is a common neurologic emergency. Diagnosis and treatment of this disorder, in the past exclusively performed by a neurologist, has in recent years become a team effort in intermediate care units. Modern management of epilepsy now benefits from developments accomplished in neuroimaging. In epileptology, magnetic resonance imaging (MRI) has two major clinical indications: first of all, identification or exclusion of a symptomatic cerebral abnormality in patients after an epileptic seizure, and secondly, characterization of epileptogenic foci for presurgical evaluation in patients with drug-resistant epilepsy. Over the last decade, new MRI methods have been developed including perfusion- and diffusion-weighted imaging that are now available for improving the non-invasive localization of an epileptogenic focus.

Up until the end of the eighties reports appeared on transient focal abnormalities observed upon computer tomography (CT) of the brain in patients with partial epilepsy [1]. Since MRI has been in use, Kramer et al. were the first to describe neuroimaging abnormalities related to focal status epilepticus [2]. Only a few studies have appeared describing MRI findings in patients after partial status epilepticus. All of these reports were based on small numbers of patients, of whom some were children [3-6]. Penfield already reported in 1933 a local hyperperfusion during an epileptic seizure while operating on a neurosurgical disorder, an abnormality that was confirmed decades later using functional MRI (fMRI), angiography and radioisotopic measurement (SPECT) [7-9].

Some study groups showed with MRI studies of the head focal hyperintensity in the temporo-medial or temporo-polar lobe after a status of complex partial seizures [29, 30]. In all of this patients the abnormalities were reversible. Optimal timing of neuroimaging with MRI can help to identify patients with a status of complex partial seizures and should also reduce the rate of misdiagnosis of other disorders.

Many conditions can imitate focal epilepsy of prolonged duration. Imaging techniques may be able to help identify such patients. EEG remains the most sensitive technique, but unfortunately it sometimes represents an insufficient marker of focal epileptic status, since EEG changes lack specificity.

MRI and Status Epilepticus

Neuroradiological methods, particularly MRI, are frequently used during a status epilepticus to exclude other neurological disorders. For this reason it has become more important to know the MRI-changes which can be caused by a status epilepticus. The important question is whether MRI changes detected represent the consequence or the cause of the status epilepticus. It is also important to know whether the radiological signs (CT-scan and MRI) of a status of complex partial seizures are similar to those related to an ischemic stroke, neoplastic processes or inflammatory diseases such as herpes-simplex-encephalitis. Most findings regarding the MRI studies were re-

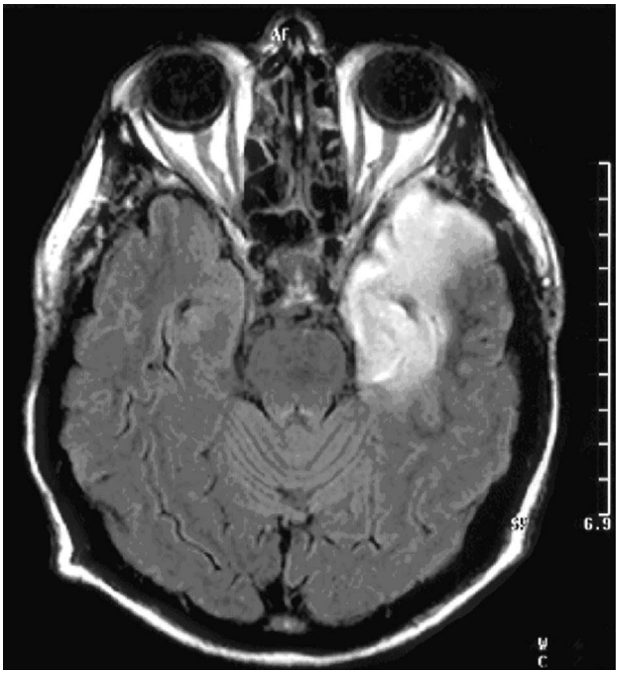

Fig. 1. The MRI revealed a hyperintensity of the left temporo-polar and temporo-medial lobes (FLAIR-Image) [29].

versible in the follow-up examinations [29]. The CSF and blood analysis revealed no association with an inflammatory disorder [30].

Diffusion- and Perfusion Weighted MRI

The reversible changes are an isolated hyperintensity in the temporo-medial or temporo-polar lobe due to an epileptic state. In particular, changes in apparent diffusion coefficient (ADC) and in diffusion-weighted imaging (DWI) have been shown by various groups both in animal models and humans [10-17]. Focal hyperintensity in MRI of these patients can be explained by hyperperfusion as a reversible process, possibly caused by an increase in metabolic demand during a status epilepticus. Raised signals in the MRI may reflect a focal neuronal and glial cell death, as has been demonstrated in some animal studies [18-19]. Epileptic activity can presumably change cerebral hemodynamics. This is another possible pathogenetic mechanism underlying reversible neuroimaging lesions occurring in association with epileptic seizures.

Until now, transient MR changes during a status epilepticus have been described in the area of the cortex and/or hippocampal structures in the most cases [12]. Such changes were demonstrated first in 1995, both after single seizures or a series of seizures [23, 24]. Using computer tomographic studies (also after seizures), reversible postictal hypodensities have been described in case reports [25]. Other morphological abnormalities appearing in the imaging were found in patients with status epilepticus in the form of an increased uptake of nucleotides in scintigraphic studies and a premature venous drainage in the angiography [12]. Postictal positron emission tomography reveals an increased perfusion and an increased metabolism in epileptic foci.

In contrast to other studies (Table 1) our own group showed transient hyperintensity on T2-weighted images (T2WI) and parenchymal gadolinium enhancement in the seizure focus (temporo-medial or temporo-polar lobe) [29]. Single cases with transient focal cortical enhancement have been reported elsewhere [11, 12, 20]. In all these reports the lesions disappeared with improved seizure control.

These findings are not only an important contribution for differential diagnosis in patients with altered consciousness; they shall also help to prevent any unnecessary diagnostic procedures from being undertaken. Furthermore, MRI can be used for the noninvasive localization of a seizure focus. Follow-up imaging may also help to specify the underlying cause. Our own results showed that transient MRI changes in partial status epilepticus differ from those observed in ischemia and that they are not always followed by cell death [29]. In the early stage of ischemia, diffusion is reduced in the ischemic area which includes both cortex and white matter. Later, if cell death is ongoing, diffusion increases [21]. Similar diffusion changes have been reported in experimental status epilepticus. In

Table 1. MRI Findings in Partial Status Epilepticus.

Author	No. of patients	Findings
Henry et al. (Epilepsia, 1994)	2	Increased signal in T2WI of the left temporal lobe (1 patient with gemistocytic astrocytoma)
Wieshmann et al. (Lancet, 1997)	1	Decreased diffusion in the motor cortex and increased signal in the subcortical white matter
Lansberg et al. (Neurology, 1999)	3	Cortical hyperintensity in T2WI, DWI and low ADC and leptomeningeal enhancement in postcontrast MRI
Krings et al. (Neurology, 2000)	1	Cortical hemodynamic changes
Hufnagel et al. (Epilepsia, 2003)	25	Focal alterations of ADC correlate with epileptogenic zone
Kavuk et al. (J Neurol, 2004)	3	Focal Hyperpeintensity in temporo-medial or temporo-polar lobe (reversible)

kainic acid-induced status epilepticus the diffusion in the area of the piriform cortex and the amygdala is at first decreased [22].

Animal Studies with MRI and Epilepsy

The often indistinctly delimited hyperintensities in the medulla and cortex that can be seen in the T2-weighted and FLAIR sequences can best be explained by an increase in water content [26]. Chan et al. suggested that a peri- and postictally occurring cytotoxic edema due to an excessive intracellular increase in glutamate was the cause for this. In one his patients (with postictal alterations in the T2 weighted sequences), a biopsy was taken from the affected temporal lobe shortly after the status epilepticus, which revealed a cytoplasmic swelling of the astrocytes upon histopathological examination. Such swellings are often found with cytotoxic edemas. After 4 years a 2nd sample was taken during an epilepsy surgical intervention. On that occasion astrocytes with a reduced volume were found. The authors concluded that the cytotoxic edema in the acute phase was responsible for the reversible changes.

Wang et al. found a raised sodium concentration in the cortex of rats during a status epilepticus presumably due to an energy-dependent failure of the Na/K pump with a subsequent cellular influx of sodium and water [27]. In addition, H1 nuclear spin resonance spectroscopy examinations in the cortical measurement areas during and after a prolonged non-convulsive seizure activity revealed raised lactate, reduced N-acetyl-aspartate and raised choline levels [28]. The cortical swelling may have been caused not just by cytotoxic edema, but also by vessel-related changes i.e. as an extracellular vasogenic edema [12, 23].

Basically diffusion weighted MRI was used for acute stroke imaging. In this phase diffusion weighted sequences showed already few minutes after cerebral artery occlusion changes of cellular diffusion activity.

Lansberg et al. [12] described a leptomeningeal enhancement in the T1 weighted sequences after gadolinium application over the afflicted hemisphere with complex partial status epilepticus as a correlate of a temporarily disrupted blood-brain barrier with consecutive vasogenic edema. In addition, the proximal sections of the MCA were expanded ipsilaterally, so that the local hyperperfusion represented another etiological characteristic for the status epilepticus.

The diffusion defects that we found, mainly in the temporal region in the diffusion weighted sequences due to water influx and a reduced cortical diffusion, do not result in cell death as is otherwise observed with ischemia induced diffusion defects, but are in fact reversible in the same way that signal enhancements in the T2 and FLAIR sequences are. Consistent with this, the cortex appeared normal in later follow-up examinations, and no circumscribed lesions were apparent. The regional atrophies described by Lansberg et al. could only be observed in one patient in the follow-up examination.

The MR abnormalities associated with partial status epilepticus reflect the fact that a seizure-induced cytotoxic and vasogenic edema appears as a transient signal change. The described findings may be useful for understanding the pathophysiology of seizure-induced brain damage in patients with epilepsy.

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