Cortical laminar necrosis related to prolonged focal status epilepticus

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Cortical laminar necrosis (CLN) is radiologically defined as high intensity cortical lesions on T1 weighted MRI images following a gyral distribution. Histopathologically, CLN is characterised by pan necrosis of the cortex involving neurones, glial cells, and blood vessels. It has been reported to be associated with hypoxia, metabolic disturbances, drugs, and infections. We present two patients who developed CLN and permanent neurological deficits after prolonged and repeated focal status epilepticus. The possible mechanisms leading to CLN in these patients are discussed, together with the implications of prompt and aggressive treatment in similar cases.

CASE DESCRIPTIONS

Patient 1
A 62 year old right handed man with history of acute bilateral otitis media was admitted after being found unconscious. An initial CT scan showed a brain abscess in the right temporal lobe. The patient developed left face clonic SE without impairment of consciousness 5 days after admission. The EEG showed periodic lateralised epileptiform discharges (PLEDs) over the right temporal region. A brain MRI showed the brain abscess as well as cortical high intensity lesions on T2 weighted images associated with mild subcortical oedema involving the right posterior temporal, parietal, and occipital regions (fig 1B, B1). These lesions were interpreted as acute changes associated with SE. The patient was administered i.v. phenytoin and the seizures stopped 3 days later. Physical examination upon discharge showed a complete right homonymous hemianopia, a mild right hemiparesis, and severe receptive aphasia which were both fully resolved in 5 days and were interpreted as a Todd’s-like phenomenon. However, 2 weeks later, the patient again experienced focal motor SE in spite of therapeutic AED levels and no obvious precipitating factor.

Treatment with phenytoin and valproic acid was maximised and oral levetiracetam was added, but seizures were not controlled until 8 days later. A brain MRI performed during SE showed cortical hyperintensity on DP/T2 weighted images in the left posterior temporal, parietal, and occipital regions (fig 1C, C1–2) in addition to the AVM. Physical examination after the SE showed a right homonymous hemianopia and mild receptive aphasia which were both fully resolved in 5 days and were interpreted as aTodd’s-like phenomenon. However, 2 weeks later, the patient again experienced focal motor SE in spite of therapeutic AED levels and no obvious precipitating factor.

Abbreviations: AED, antiepileptic drug; AVM, arteriovenous malformation; CLN, cortical laminar necrosis; CVR, cerebrovascular reserve; NO, nitric oxide; PLEDs, periodic lateralised epileptiform discharges; SE, status epilepticus
aphasia. The right hemiparesis resolved within approximately 1 week, but the right homonymous hemianopia and the receptive aphasia remained unchanged 7 months later. Follow up MRI at this time shows persisting CLN with the same distribution on the left posterior quadrant.

**DISCUSSION**

Transient radiological changes, such as hyperintense cortical lesions in T2, FLAIR, and diffusion weighted images, have been reported in patients with focal SE.2–4 Our two patients displayed these acute changes during focal motor SE. MRI changes during SE are reversible in most patients, but in some cases permanent brain damage has been reported.1–4

Our two patients displayed permanent brain imaging abnormalities consistent with CLN after prolonged focal SE. Radiologically, CLN is characterised by high intensity cortical lesions on T1 weighted and FLAIR images following a gyral distribution, associated with volume loss over the underlying cortex. CLN has been described associated with hypoxia, metabolic disturbances, drugs, infections,9 and SE. Only three cases of CLN associated with SE have been previously reported, and all had severe hypoglycaemia or hypoxia during the episode.5–10 In contrast, our two patients did not show any metabolic disturbances or significant decreases in blood pressure during the episodes of focal SE. The hypothesis that the necrosis observed in these patients is primarily a consequence of repeated seizures is further supported by the fact that CLN is seen in the same areas as those displaying acute cortical oedema and hyperperfusion (as shown by ictal SPECT in patient number 1) during the acute phase of SE. Furthermore, these hyperintense lesions did not involve separate vascular territories and occurred at a distance from the structural lesions. The location of CLN was also concordant with the location of continuous epileptic activity shown by surface EEG during SE.

It can be speculated that CLN in the first patient was due to cerebritis in the context of a brain infection; however, the absence of focal neurological deficits during and after the first episode of SE (when the abscess was active) and the appearance of focal neurological deficits after the second SE, when the infectious process was inactive, makes this hypothesis very unlikely. In the second patient, a haemodynamic ischaemic event (“steal phenomenon”) related to the AVM as well as a venous infarction in the context of hyperperfusion secondary to SE in a vascular bed with impaired vasoreactivity, can be reasonably ruled out as the main pathogenic mechanism. As there are no signal changes in the white matter under the involved cortex reflecting vasogenic oedema or blood-brain barrier rupture and also because the CLN extends far beyond the AVM and crosses vascular territories.

In our patients, CLN correlated clinically with severe focal neurological deficits (cortical sensory disturbance in patient number 1, hemiparesis, aphasia, and hemianopia in patient number 2) which have remained unchanged over time. Therefore, prolonged focal SE can cause permanent brain damage; this is the first time that CLN has been described as being associated with focal SE in the absence of other metabolic or toxic factors. Many mechanisms can lead to permanent brain damage as a result of SE. Status epilepticus causes a large increase in cerebral metabolic demand for glucose and oxygen and there is, therefore, a compensatory increase in cerebral blood flow. If blood flow is not sufficient, adenosine triphosphate depletion and lactate accumulation occur, leading to hypermetabolic neural necrosis.11 Experimental animal studies have shown that correlation between regions with excessive metabolism and the distribution and extent of seizure induced neuronal damage is quite good.12 There are also excitotoxic mechanisms mediated by both NMDA and non-NMDA receptors resulting in Ca2+ entry and release of Ca2+ from intracellular stores which plays a major role in neuronal injury from SE.13–14

The location of the lesions, in the posterior quadrant of the cerebral hemispheres in our patients, may be related to the poverty of sympathetic innervation of the vessels arising from the basilar artery; it is known that this innervation plays a fundamental role in cerebrovascular reactivity that leads to coupling between cortical activity and cerebral blood flow.13–14

Figure 1 (A) Ictal 99mHMPAO SPECT demonstrating right temporo-parieto-occipital hyperperfusion. (B1–2) Axial T2 weighted images showing cortical increased signal intensity of the right temporo-parieto-occipital regions compatible with transient radiological changes associated with SE. B1 corresponds to the first SE. Notice the extensive cortical and white matter oedema associated with the brain abscess compared to the exclusively cortical oedema related to radiological changes associated with SE. The patient recovered after the first SE without significant neurological deficits. B2 corresponds to the second SE. At this time the oedema was mostly cortical and there were no signs of acute infection in the temporal region. (B3–4) Follow-up MRI, 3 weeks after the second SE. Axial and sagittal T1 weighted images show a high intensity cortical laminar lesion following a gyral distribution associated with volume loss in the right posterior temporal, parietal, and occipital regions, indicative of CLN. Notice also a hyperintense lesion on T1 weighted images located at the posterolateral portion of the ipsilateral thalamus (C2). (C1–2) Axial T1/T2 weighted images showing cortical increased signal intensity on T2 weighted images (C1) of the left parietal region and decreased signal intensity in the exact same location in T1 weighted images (C2) during the first SE. Notice the absence of hyperintense cortical lesions in the posterior quadrant during the first SE in C2. (C3–4) Follow up MRI, 1 week after the second SE. Axial and sagittal T1 weighted images show a high intensity cortical lesion following a gyral pattern associated with volume loss in the left posterior temporal, parietal, and occipital regions.
Furthermore, experimental animal studies examining vasoreactivity in response to nitric oxide (NO) assessed by cerebral angiography, showed that the vascular response to NO was greater in the posterior than the anterior circulation. Taking into account the fact that basal release of NO contributes to the maintenance of the resting vascular tone, it could be hypothesised that the posterior circulation is more dilated under baseline conditions and therefore has less capacity for further vasodilatation when needed. This may lead to a reduced cerebrovascular reserve (CVR) and uncoupling between the cortical metabolic demand and the cerebral blood flow in those situations in which high metabolic demands are required, such as focal SE. However, this needs to be confirmed, as other human studies assessing CVR and CO₂ reactivity using transcranial Doppler ultrasound have not found significant differences in vasoreactivity between the vertebral-basilar and carotid systems.16 17

In conclusion, most of the radiological cortical signal changes associated with focal SE seem to be reversible. However, a group of patients may display permanent brain damage after SE, with radiological changes suggestive of CLN and accompanying focal neurological deficits. It is possible that patients who display hyperintense cortical signal changes during the acute phase of SE are more at risk of developing permanent brain damage, but larger series of patients with follow up MRI studies are needed to answer this question. It is also unclear if certain cortical areas are more susceptible to seizure induced permanent damage and cortical necrosis. Interestingly enough, our patients had focal SE involving the posterior quadrant of the hemisphere. The possibility of permanent brain damage after focal SE, even without alteration of consciousness, should encourage prompt and aggressive treatment of recurrent seizures.

References

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