Occipital activation in glyceryl trinitrate induced migraine with visual aura

S Afridi, H Kaube, P J Goadsby

A case of migraine is presented with visual aura triggered on two separate occasions by glyceryl trinitrate (GTN). Positron emission tomography was carried out during the second triggering session. Activation in the primary visual area of the occipital cortex was demonstrated during the aura. This is the first published case of migraine aura triggered reproducibly by GTN.

A 54 year old male with episodic migraine with aura volunteered to participate in a positron emission tomography (PET) study in migraine. He had a history of migraine with aura as defined by the International Headache Society (IHS) criteria since his teenage years, with a frequency of up to eight attacks per month, each lasting up to one day if left untreated. A typical attack would begin with visual aura in the form of bright, flashing zig-zag shapes moving around his visual field and rarely he experienced macropsia. The visual aura would last 10 to 20 minutes and would be followed by a left sided migrainous headache. Subcutaneous sumatriptan (6 mg) was then given to the subject and the migraine attack was successfully aborted.

PET scanning and analysis
The subject was scanned before the infusion, while pain-free, and during the aura and headache phases of migraine. He described the onset of the aura, and scanning of the aura phase began immediately following this description. PET was carried out with an ECAT EXACT HR+ scanning system (CTI Siemens, Knoxville, Tennessee, USA) in three dimensional mode with septa retracted. He had his eyes closed throughout the scanning sessions. An antecubital vein cannula was used to give the tracer (350 mBq of $^{15}$O). The activity was infused into subjects over 20 seconds at a rate of 10 ml/min.

The data were acquired in one 90 second frame beginning five seconds before the peak of the head curve. The subject had a total of 12 scans, two of which were during the aura. The aura subsided during the second of the scans. The interval between scans was eight minutes. Attenuation correction was carried out with a transmission scan acquired at the beginning of each study. Images were reconstructed by filtered back projection into 63 image planes (separation 2.4 mm) and into a 128×128 pixel image matrix (pixel size 2.1×2.1 mm$^2$). SPM99 (Wellcome Department of Imaging Neuroscience, http://www.fil.ion.ucl.ac.uk/spm) was used for data analysis.

Analysis of the PET data revealed right sided occipital activation when comparing the two scans taken during the aura. Images were realigned with the first as the reference and then co-registered, and finally spatially normalised into the space defined by the atlas of Talairach and Tournoux. The normalised images were smoothed with a Gaussian filter of 10 mm full width at half maximum. Statistical parametric maps were derived with prespecified contrasts, comparing regional cerebral blood flow during aura versus rest. An uncorrected threshold of p<0.001 was chosen for tabular and graphical reporting.

Analysis of the PET data revealed right sided occipital activation when comparing the two scans taken during the visual aura with those taken immediately before the GTN infusion (fig 1). The activation was in the primary visual region (V1) of the occipital cortex (Brodmann area 17). This area has a very high degree of retinotopic precision and orientation selectivity. No significant activation was observed in the V1 region of seven other patients with IHS.
defined migraine with aura who developed migraine without aura following GTN administration.\textsuperscript{15}

**DISCUSSION**

As far as we are aware there have not been any published reports of PET activation in the primary visual cortex during visual aura. Earlier studies using PET and single photon emission computed tomography (SPECT) showed spreading hyperperfusion in the occipital cortex in migraine with aura.\textsuperscript{14–17} More recently, functional MRI has been used in migraineurs to investigate occipital cortex activation during visual stimulation with a checker board. In one of these studies an initial increase in blood flow was demonstrated in the extrastriate cortex (V3A).\textsuperscript{6} This signal progressed across the occipital cortex (including V1) and was followed by diminution of the signal. The authors proposed that these changes represented cortical spreading depression. In a previous fMRI study\textsuperscript{18} the process was described in another subject with visually triggered visual aura. In this case it was initiated in the primary visual cortex and then spread antilerolaterally. Unfortunately the relatively poor temporal resolution of PET did not allow us to follow the progression of the aura more closely in our case.

GTN is a nitric oxide (NO) donor which has previously been shown to trigger migraine attacks in migraineurs. In a study of 12 subjects with migraine with aura, GTN was found to trigger an attack of migraine without aura in six of the subjects but failed to induce the aura in these.\textsuperscript{19} However, in a recent study by Sances and colleagues\textsuperscript{19} involving 197 migraineurs it was found that of the 22 subjects with migraine with aura, migraine without aura was triggered in six subjects and migraine with aura in three (13.6%). The success rate of the trigger was higher (82%) in the subjects with migraine without aura. Our patient was a participant in a study involving GTN triggering of migraine and was one of two patients in whom migraine aura was triggered.\textsuperscript{15} Unfortunately the second patient did not undergo PET scanning. In the aforementioned study migraine without aura was triggered in a further 12 patients with migraine with aura. The mechanism by which GTN triggers migraine is unclear but it is thought that the exogenous NO from the GTN may induce endogenous NO production. Animal studies have also revealed that cortical spreading depression, which is thought to be responsible for migraine aura in humans, elicits widespread release of NO and increased cortical concentrations of cyclic guanosine monophosphate (cGMP).\textsuperscript{20}

Other possible causes for the occipital activation in this patient include the possibility that he opened his eyes during the scanning, although the patient denies this and if this was the case then one would expect a much greater pattern of activation in the visual cortex than that observed. Another possibility is that the GTN is responsible for vasodilatation in the occipital cortex. However, the region of activation is localised and unilateral and one would expect a GTN related flow change to be bilateral and generalised. In fact bilateral hyperperfusion rather than hyperperfusion has been documented in the occipital cortex following GTN administration to healthy controls.\textsuperscript{15} It is possible that some inherent neurovascular asymmetry exists in the brains of migraineurs which may alter the vascular response to GTN. However, this does not explain the lack of significant activation in the V1 region in any of the other patients with migraine with aura who received GTN infusions. It is also of interest to note that activation in V1 has been documented during visual mental imagery, in particular when the subjects are required to imagine high resolution detailed images.\textsuperscript{21}

Ours is the first case to show that aura can be triggered reproducibly by GTN, making it less likely that the aura was spontaneous or developed by chance in this situation. The fact that the site of activation was contralateral to the headache does not contradict our explanation for the findings, as we are proposing that the V1 activation is related to the aura and not the headache. Clinical and experimental observations\textsuperscript{22–25} have shown that aura symptoms are not always contralateral to headache and consequently aura associated changes in brain activation may be contralateral to headache. While some take the view that aura triggers headache,\textsuperscript{26} others have argued for a dissociation.\textsuperscript{27}

In conclusion, we present evidence for the reproducibility of GTN as a trigger of migraine aura. While the number of patients who can have aura reliably re-triggered are small, such cases clearly exist and may offer insights into the neuroanatomical correlates of this fascinating clinical symptom.

**Authors’ affiliations**

S Afridi, H Kaube, P J Goadsby, Headache Group, Institute of Neurology and The National Hospital for Neurology and Neurosurgery, Queen Square, London WC1, UK

Correspondence to: Professor Peter J Goadsby, Headache Group, Institute of Neurology, Queen Square, London WC1N 3BG, UK, peterg@ion.ucl.ac.uk

Received 26 July 2004

In revised form 21 November 2004

Accepted 1 December 2004

**REFERENCES**

8 Laws GL. The effects of nitroglycerin upon those who manufacture it. JAMA 1898;31:793–4.
20 Reed SJ, Hirat WD, Lipton N, et al. Cortical spreading depression produces increased cGMP levels in cortex and brain stem that is inhibited by tonabersat (5B-220453) but not sumatriptan. Brain Res 2001;891:69–77.