AJNR

Stereotactic location and excision of seizure focus with xenon-enhanced CT.

A A Patil, J R McConnel and R D Torkelson

AJNR Am J Neuroradiol 1995, 16 (4) 644-646
http://www.ajnr.org/content/16/4/644

Stereotactic Location and Excision of Seizure Focus with Xenon-Enhanced CT

Arun-Angelo Patil, James R. McConnel, and Richard D. Torkelson

Summary: A case of intractable seizures, originating in the motor cortex, was successfully treated with excision of the seizure focus after precise location of the focus on depth electrode recordings. The depth electrode was placed stereotactically with coordinates from xenon-enhanced CT images. Prior attempts at treating the seizures with ablation of seizure foci had resulted in disappearance of seizure activity on electrocorticography study without cessation of clinical seizures.

Index terms: Xenon; Surgery, stereotactic; Seizures

To excise epileptogenic foci safely and effectively in critical areas of the brain, precise location of the foci is required. If the seizure focus is on the surface of the brain, it can be located by studying the electrical activity using electrocorticography (ECG). If the seizure focus is deep in the brain, surface ECG recordings may fail to show or locate the seizure focus. Location of the seizure focus in such cases may be achieved by functional neuroimaging modalities such as the positron emission tomography (PET) (1–3), single-photon emission computed tomography (SPECT) (4–6) and xenon-enhanced computed tomography (Xe CT) (7).

We report a case of epilepsia partialis continua in which Xe CT scan assisted in locating the seizure focus.

Case Report

The patient is an 11-year-old right-handed girl with a 9-year history of seizures involving the left side of her body. A seizure disorder characterized by simple partial, complex partial, and secondarily generalized seizures with residuae of left hemiparesis (hemiconvulsions, hemiparesis, and epilepsy syndrome) developed. In September 1991 she was admitted for epilepsia partialis continua involving the left side of her body. A magnetic resonance scan was obtained. This showed a slight increase in signal intensity on T2-weighted images in the area of the right motor cortex (Fig 1A). An ictal SPECT scan using technetium 99m hexamethyl-propyleneamine oxime (HMPAO) showed a large area of hyperperfusion over the right frontoparietal cortex (Fig 1B). After medical treatment failed to stop the seizures, based on information obtained from ECG that was performed using a subdural grid, subpial transection (8) was performed over a large area in the right frontoparietal cortex. This procedure normalized the ECG but did not stop the clinical seizures. A PET scan using fludeoxyglucose F 18 and a SPECT scan using technetium 99m HMPAO were obtained. The patient had continuous seizures during tracer uptake in both of these studies. Both studies showed increased uptake of their respective tracers in the right motor cortex (Figs 1C and D).

The PET scan then was repeated with the intent of obtaining coordinates for stereotactic-guided excision of the seizure focus. During the 40 minutes of tracer uptake, the patient had seizures for only 5 minutes. The PET scan failed to show the focal area of abnormality that was seen on the previous study. A Xe CT cerebral blood flow study was performed. The patient had seizures during the entire 4.5 minutes of the Xe study. The study showed a small area of increased perfusion in the right motor cortex (Fig 1E). A surgical procedure for excision of the seizure focus using Xe CT stereotactic guidance was planned. After the patient was anesthetized and placed in the Patil stereotactic frame (9) that was mounted on the CT table, a Xe CT study was performed. Seizure activity was present for only 30 seconds of the 4.5 minutes of study. Xe CT image now showed an area of decreased blood flow in precisely the same location in which the previous study (Fig 1F) had shown hyperperfusion. The patient, with her head fixed in the stereotactic frame, then was moved to the operating room. After the craniotomy was reopened, ECG was performed. The recordings showed no seizure activity. A depth electrode with four contacts was stereotactically inserted through the probe holder of the stereotactic frame, into the area of hypoperfusion. Recording from the contact at a depth of 1.5 cm from the brain surface showed evidence of seizure activity. The gyrus in which this recording was obtained was excised. Histology of the tissue revealed

Received December 17, 1992; accepted after revision June 18, 1993.

From the Departments of Neurosurgery (A.-A.P.), Radiology (J.R.M.), and Pediatrics (R.D.T.), University of Nebraska Medical Center, Omaha.

Address reprint requests to Arun-Angelo Patil, MD, Department of Neurosurgery, University of Nebraska Medical Center, 600 S 42nd St, Omaha, NE 68198-2035.

AJNR 16:644–646, Apr 1995 0195-6108/95/1604–0644

Fig 1. *A,* T2-weighted magnetic resonance scan shows an area of increased signal in the right motor cortex.

B, An ictal SPECT scan (right lateral view) before the first surgery shows an area of hyperperfusion in the right frontoparietal cortex. *A* indicates anterior and *P*, posterior.

C, Ictal PET scan using fludeoxyglucose F 18 after the first surgery shows a well-circumscribed area of increased tracer uptake in the right motor cortex.

D, Ictal SPECT scan (right lateral view) obtained after the first surgery shows a small area of hyperperfusion in the right motor cortex. *A* indicates anterior and *P*, posterior.

E, Ictal Xe CT scan obtained after the first surgery shows increased xenon uptake (red oblong spot surrounded by a yellow rim) in the right motor cortex.

F, Interictal Xe CT scan obtained after the first surgery shows an area of decreased perfusion (*arrowheads*) in the right motor cortex.

marked gliosis and neuronal degeneration without evidence of inflammatory process. After the operation, the seizures on the left side of her body have completely resolved, and the patient continues to be free of these seizures at 41 months' follow-up, without any new neurologic deficits.

Discussion

An increased metabolic rate at the seizure focus is reflected by an increased rate of glucose metabolism on PET scan (using fludeoxyglucose F 18 as tracer) obtained during an ictus, whereas the reverse is seen during the interictal period (1–3). Regional blood flow parallels the glucose metabolic rate as detected by SPECT using technetium 99m HMPAO as a tracer; hence changes similar to those seen with PET can be demonstrated on SPECT studies (4–6). Stable Xe has been used to study regional cerebral blood flow with the CT scanner in cerebrovascular disease (10–12). Fish et al (7) reported the use of Xe CT in the investigation of seizure disorders. They found that the seizure focus had hypoperfusion if the study was performed during the interictal period. Our patient's first Xe CT demonstrated that hyperperfusion can be shown on Xe CT study if the Xe CT is done during the ictal period. It is of interest that the area of increased Xe uptake on Xe CT corresponded to the area of increased uptake of

their respective tracers on SPECT and PET studies. We believe the second Xe CT and the second PET studies failed to show hyperperfusion and hypermetabolism, respectively, in the seizure focus because the patient had a seizure only for a fraction of the time during the studies. These results suggest that the chances of obtaining images, with hyperperfusion in the seizure focus on SPECT and Xe CT studies and hypermetabolism in the seizure focus on PET studies, is greatly increased if the patient is in the ictal period during the entire study. An ictal study could be ruined by movement associated with seizures. However, because the study in our case was performed with the patient's head secured in the stereotactic frame, which in turn was secured to the CT table, a good study was obtained.

In order to locate accurately a small seizure focus in critical areas of the brain, it is important that the image of the seizure focus be sharply demarcated. Because scans with hypermetabolism or hyperperfusion show the seizure focus sharper than those with hypometabolism or hypoperfusion, they are preferred. In our patient we were able to locate the seizure focus accurately even on the second Xe CT study, which showed the seizure focus as an area of hypoperfusion, because the first Xe CT study had already indicated to us the area of the seizure focus. In SPECT studies, the uptake time for the commonly used tracer technetium 99m HMPAO is within a minute. However, the resolution of images on SPECT scan is not adequate for stereotactic procedures. PET scans and Xe CT scans provide images of adequate resolution for stereotactic procedures. However, the resolution of the CT images attributable to their smaller pixel sizes is superior to the PET images, and the xenon inhalation time of 4.5 minutes for the Xe CT study is much shorter than the uptake time of 40 minutes for the commonly used tracer fludeoxyglucose F 18 in the PET studies. These factors make Xe CT study preferable to PET study if stereotactic location of a relatively small seizure focus is indicated.

In our patient, subpial transection was our first surgical choice, because although preoperative magnetic resonance showed structural abnormality, the ECG and SPECT scan showed a large area of seizure activity over the frontoparietal cortex, which encompassed the motor strip. Excision of such an area would have resulted in severe neurologic deficits. After the first operation, the seizure focus as seen on the SPECT, PET, and Xe CT scans was significantly smaller. This made surgical excision of the focus relatively safer.

We conclude that the Xe CT study provides a means of accurately locating seizure foci and therefore could be used in conjunction with stereotactic procedures for placement of depth electrodes and excision of discrete seizure foci. Further studies are needed to assess the usefulness of this technique.

References

1. Engel J, Kuhl DE, Phelps ME, Crandall PH. Comparative localization of epileptic foci in partial epilepsy by PCT and EEG. *Ann Neurol* 1982;12:529–537
2. Mazziotta JC, Engel J. The use and impact of positron computed tomography scanning in epilepsy. *Epilepsia* 1984;25(suppl 2): S86–S104
3. Theodore WH, Newmark ME, Sato S, et al. F-18-fluorodeoxyglucose positron emission tomography in refractory complex partial seizures. *Ann Neurol* 1983;14:429–437
4. Katz A, Bose A, Lind SJ, Spencer SS. SPECT in patient with epilepsia partialis continua. *Neurology* 1990;40:1848–1850
5. Lee BI, Markand ON, Siddiqui AR, et al. Single photon emission computed tomography (SPECT) brainimaging using N,N,N′-trimethyl-N′-(2 hydroxy-3-methyl-5-^{123}I-iodobenzyl)-1,3-propanediamine 2 HCl (HIPDM): intractable complex partial seizures. *Neurology* 1986;36:1471–1477
6. Stefan H, Kuhnen C, Biersack HJ, Reichmann K. Initial experience with 99m Tc-hexamethyl-propylene amine oxine (HM-PAO) single photon emission computer tomography (SPECT) in patients with focal epilepsy. *Epilepsy Res* 1987;1:134–138
7. Fish DR, Lewis TT, Brooks DJ, Zilkha E, Wise RJS, Kendall BE. Regional cerebral blood flow of patients with focal epilepsy studied using xenon enhanced CT brain scanning. *J Neurol Neurosurg Psychiatry* 1987;50:1584–1588
8. Morrell F, Whisler WW, Bleck TP. Multiple subpial transection: a new approach to the surgical treatment of focal epilepsy. *J Neurosurg* 1989;70:231–239
9. Patil A, Kumar P, Leibrock L, Gelber B, Aarabi B. The value of intraoperative scans during CT-guided stereotactic procedures. *Neuroradiology* 1992;34:453–456
10. Gur D, Wolfson SK, Yonas H, et al. Progress in cerebrovascular disease: local cerebral blood flow by xenon enhanced CT. *Stroke* 1982;13:750–758
11. Meyer JS, Hayman LA, Amano T, et al. Mapping local blood flow of human brain by CT scanning during stable xenon inhalation. *Stroke* 1981;12:426–436
12. Yonas H, Wolfson SK, Gur D, et al. Clinical experience with the use of xenon-enhanced CT blood flow mapping in cerebral vascular disease. *Stroke* 1984;15:443–450