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# Ictal SPECT analyzed by three-dimensional stereotactic surface projection in frontal lobe epilepsy patients

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**Abstract**

We analyzed preoperative ictal SPECT results from 18 frontal lobe epilepsy patients who underwent epilepsy surgery (mean age 22.9 years). Seizure onset at implanted subdural electrodes was defined as the epileptic focus in 16 of 18 patients. In two additional patients, the resected area on postoperative magnetic resonance images was defined as the epileptic focus. The radioisotope $^{99m}$Tc-ECD was injected in all patients within 5 s after seizure onset. SPECT images were analyzed by three-dimensional stereotactic surface projection (3-D SSP). Areas of hyperperfusion identified by ictal SPECT were concordant with the site of epileptic focus in 11 patients (61.1%, concordant group) and were non-concordant in 7 patients (38.9%, non-concordant group). The non-concordant group had a higher number of patients with a history of acquired brain damages, such as encephalitis or brain surgery ($p < 0.05$). Only 3 of 11 patients in the concordant group showed areas of localized hyperperfusion within epileptic foci, whereas 8 patients showed areas of hyperperfusion extending to other regions. Ictal SPECT analyzed by 3-D SSP is useful as a mode of presurgical evaluation in frontal lobe epilepsy patients without a history of encephalitis or surgical treatment. We caution that rapid seizure spread may result occasionally in areas of hyperperfusion extending to adjacent or remote regions.


*Keywords:* Epilepsy surgery; Frontal lobe epilepsy; Ictal SPECT; 3-D SSP

## 1. Introduction

Recent improvements in surgery for intractable epilepsy have yielded improved outcomes in many patients. Successful surgery is more elusive for frontal lobe epilepsy (FLE) than for temporal lobe epilepsy (TLE), however. FLE comprises a heterogeneous group

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of seizure disorders characterized by a variety of seizure types and etiologies. It is difficult to localize the epileptic foci in FLE patients because the extensive neural network of subcortical connections in the frontal lobe can lead to rapid and distant spread of seizure activity (Ludwig et al., 1976; Williamson and Spencer, 1986). Structural abnormalities identified by magnetic resonance (MR) imaging do not always correspond to epileptic foci (Harvey et al., 1993).

Ictal single photon emission computed tomography (SPECT) is an important tool for presurgical evaluation to localize the epileptogenic region during partial seizures. Previous studies have shown that ictal SPECT reliably localizes the region of seizure onset in both temporal and extratemporal epilepsy (Harvey et al., 1993; Marks et al., 1992; Newton et al., 1995; Devous et al., 1998; Oliveira et al., 1999). Recent computed-aided techniques that produce peri-ictal/interictal subtraction images coregistered with MR images (SISCOM) can enhance the utility of ictal SPECT and can be used to predict the outcome of surgery in patients with temporal or extratemporal epilepsy (O'Brien et al., 2000; Lee et al., 2002a,b; Kaiboriboon et al., 2002; Bouilleret et al., 2002; Shin et al., 2002). In the present study, we determined whether ictal SPECT analyzed by three-dimensional stereotactic surface projection (3-D SSP) (Minoshima et al., 1995) provides preoperative confirmation of epileptic foci in FLE patients.

## 2. Subjects and methods

### 2.1. Subjects (Table 1)

This study included 18 patients (13 men and 5 women) with medically refractory epilepsy of frontal lobe origin who had successful seizure outcome after surgery (Engel class 1 or 2). The follow-up period ranged from 12 to 92 months (mean 60.3 months). MR images were normal in 4 patients and abnormal in 14. Abnormal findings on MR images included focal cortical dysplasia (FCD) in seven patients, dysembryoplastic neuroepithelial tumor in one, multiple tuberous sclerosis in one, and ulegyria in one. Three patients had previously undergone brain surgery because of lesions, such as ganglioglioma or cavernous angioma, or because of trauma. One patient presented with not only right partial motor seizures but also mental retardation and right hemiparesis resulting from encephalitis suffered at 9 months of age. Each patient underwent ictal SPECT during presurgical evaluation with video- and scalp EEG monitoring. Clinical data are summarized in Table 1.

Subdural electrodes were implanted in all patients except one (patient 10) who presented with violent complex gestural automatism. Ictal SPECT was used to determine the areas where the subdural electrodes should be implanted, especially in four patients whose MR images were normal. In the patient (patient 10) without subdural electrodes, ictal SPECT influenced to confirm whether the lesion based on MR images cause epileptic seizure. After complete resection of the lesion indicative of FCD based on MR images, this patient remained seizure-free. In 16 of 17 patients who underwent invasive studies, seizure onset zone on the implanted subdural electrodes was confirmed and resected. In the patient with left frontal ulegyria (patient 11), localized seizure onset was not obtained during subdural electrode monitoring. After resection of the ulegyria and adjacent areas showing frequent interictal spikes, this patient was seizure-free. In all patients, the resected area on postoperative MR images was defined as the epileptic focus.

### 2.2. Ictal SPECT imaging

Ictal injections of radioisotope were performed during seizures experienced while the patients were undergoing inpatient video-EEG monitoring. The radioisotope $^{99m}$Tc-ECD was already placed into an intravenous line and injected immediately after seizure onset by personnel well acquainted with the patient's seizures and who were stationed at the bedside. The time of seizure onset was defined as the time of earliest indication of abnormal movements or behavior or of impaired awareness. The interval from seizure onset to time of injection was no more than 5 s.

SPECT images were acquired within 30 min after radioisotope injection. Projection data were acquired with a Picker PRISM 2000 XP camera mounted with high-resolution fan beam collimators. Data were acquired in $128 \times 128$ matrices over a 20-min period