

Original Article

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Surgical Prognostic Value of Epileptic Aura Based on History and Electrical Stimulation

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Background and Purpose: We attempted to evaluate the surgical prognostic value of various types of aura in conjunction with the results of other presurgical evaluations in patients with an intracranial ictal onset zone confirmed by invasive studies and focal resection. We also attempted to determine how often the habitual auras could be elicited and to demonstrate the prognostic value of these stimulation-induced auras (SIAs).

Methods: We reviewed retrospectively the records of patients who had undergone intracranial electroencephalography evaluation and focal resective surgery for intractable partial epilepsy between 1995 and 2009. We identified the localizing value and prognostic value of the patients' auras. We correlated the resection of the area with SIA and surgical outcome.

Results: Aura was reported in 225 out of 300 patients. Patients with medial temporal lobe epilepsy (TLE) or occipital lobe epilepsy had a higher chance of having aura. The presence of aura, medial TLE, hippocampal sclerosis on pathology, focal lesions on magnetic resonance imaging (MRI), and ipsilateral abnormality on fluorodeoxyglucose-positron emission tomography were significantly correlated with seizure-free outcome. The presence of auditory aura, parietal lobe epilepsy, multifocal epilepsy, and dual pathology was associated with poor outcomes. Multivariate analysis revealed that auditory aura, multifocal epilepsy, hippocampal sclerosis, and lesion on MRI were prognostic factors for intractable partial epilepsy. SIA was observed in 29 out of the 134 patients who had habitual aura on history. The degree of complete resection of the area with SIA was not related to seizure-free outcome.

Conclusions: The presence of aura favors good surgical outcome and certain types of aura, such as auditory aura, have poor prognostic value. SIA, which was encountered in 21.6% of patients, was not related to seizure-free outcome. (2019;9:111-118)

Key words: Epilepsy, Surgery, Aura, Electrical stimulation, Prognosis

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Introduction

Aura is the first ictal symptomatology in partial epilepsy, which presents an ictal symptomatogenic zone.¹ Although it is not present in every epilepsy patient, when it is present, it can provide important information regarding the localization and lateralization of the ictal onset zone in partial epilepsy. However, the relationship between surgical prognosis and the presence of various types of aura has not been well studied, especially based on a large number of patients. Furthermore, the meaning of aura in predicting surgical prognosis should be interpreted in conjunction with other components of presurgical evaluation. This has not been attempted to date.

Accurate localization of the ictal onset zone by intracranial electrodes is one of the most sensitive and important parameters for the success of epilepsy surgery.²⁻⁵ The objectives of intracranial electroencephalography (EEG) are to define interictal abnormalities and the ictal onset zone, and to map cortical function.⁶ The primary purpose of electrical stimulation mapping is to identify essential areas for brain function, such as language and motor areas. Many clinical responses can be elicited by electrical stimulation.⁷⁻⁹ In addition to these functional mapping advantages, some epileptologists have found electrical stimulation to be of value in confirming the location of the epileptogenic zone via the induction of aura or habitual seizures in some patients.¹⁰⁻¹² However, exactly how frequently patients'

habitual aura can be elicited by intracranial electrical stimulation remains unknown. Furthermore, there are no data regarding the relationship between the resection of areas in which electrical stimulation can evoke habitual aura and surgical outcome.

We attempted to identify various types of aura in patients with a confirmed intracranial ictal onset zone and focal resection. We evaluated the localizing value of these auras. More importantly, we evaluated the surgical prognostic value of these auras in conjunction with the results of other presurgical evaluations. We also attempted to determine how often habitual auras could be elicited in these patients and to demonstrate the prognostic value of these stimulation-induced auras (SIAs).

Methods

Patients

We reviewed retrospectively the records of all consecutive patients who had undergone intracranial EEG evaluation and focal resective surgery for intractable partial epilepsy between 1995 and 2009 at the Seoul National University Hospital (SNUH). Approval from the SNUH Review Board was obtained. All patients had been followed up for more than 1 year after surgery and had undergone presurgical evaluations including magnetic resonance imaging (MRI), long-term scalp and intracranial video-EEG monitoring, fluorodeoxyglucose-positron emission tomography (FDG-PET), and ictal-interictal subtraction single-photon emission computed tomography (SPECT), if available. We excluded patients who were mentally retarded, too young to describe aura, or followed up for less than 1 year after surgery.

Definition and classification of auras

Aura was defined as the portion of the seizure that occurs before consciousness is lost and for which memory is retained afterwards. We classified the various types of aura into somatosensory, visual, auditory, vertiginous, olfactory, gustatory, epigastric or abdominal, emotional, psychic, autonomic, and sexual auras. If the patients clearly recognized their seizure onset but could not describe their symptoms, we categorized these auras as indescribable auras.

SIA was defined as the elicitation of the patient's habitual aura by electrical stimulation. Only auras that occurred without afterdischarge were regarded as SIA. We located the electrodes that evoked the patient's aura by electrical stimulation and compared them with the intracranial irritative zone and the ictal onset zone. We also tried to identify the relationship between the degree of resection

of electrode areas and SIA and surgical prognosis.

Intracranial EEG and electrical stimulation

Intracranial EEG recordings were obtained using a 128-channel Telefactor Beehive Horizon digital video monitoring system. Intracranial electrodes were arranged mainly in grids and strips, with occasional supplementary depth electrodes. The location of intracranial electrodes was determined based on one clinical, imaging, and scalp EEG data obtained during noninvasive evaluation. In patients with a lesion that was demonstrated on MRI, intracranial electrodes were placed over the lesion and the surrounding area, including the eloquent cortex. In patients without MRI lesion, the electrode locations were guided by the results of ictal scalp EEG, FDG-PET, and subtraction SPECT studies, as well as symptomatology. A more widespread coverage of the neocortex was performed in these nonlesional cases.

Electrical stimulation was carried out extraoperatively after recording spontaneous seizures. Before stimulation, sufficient antiepileptic drugs were administered. Stimulation consisted of 5 to 7 seconds trains of 50 Hz with alternating positive and negative pulses that lasted 0.3 ms and were delivered by a Grass S12 isolated biphasic stimulator. The intensity of electrical stimulation was increased until there was a positive response, the appearance of afterdischarge, or the intensity reached 15 mA. Stimulation was conducted in both bipolar and referential manners. If the habitual aura was detected without spreading afterdischarge at certain electrodes, the position of the electrodes was identified. The relationship between the position of electrodes that produced habitual auras and intracranial irritative or ictal onset zones was documented.

Other presurgical evaluations

A multidisciplinary presurgical evaluation was performed. All patients underwent thorough history-taking and physical/neurological examinations. They also underwent brain MRI using an epilepsy protocol as described previously.¹³ MRI was performed on 1.5-tesla or, from 2003, 3-tesla systems. Our imaging protocol included 3 mm T₂-weighted/fluid-attenuated inversion recovery oblique coronal images and 1.5 mm T₁-weighted three-dimensional magnetization-prepared rapid acquisition with gradient-echo sequences. An experienced neuroradiologist who was blinded to other presurgical evaluation findings viewed the MRI first. The second interpretations were performed at a multidisciplinary case conference based on data from video-EEG monitoring, FDG-PET, and ictal-interictal SPECT, if available.

Continuous video-EEG monitoring was performed in all patients to capture at least three habitual seizures. The international 10-20 system and additional anterior temporal electrodes were used for scalp EEG monitoring. Interictal epileptiform discharges and ictal-onset rhythms were classified as localizing if they were confined to the electrodes of the epileptogenic lobe. If possible, functional neuroimaging studies were performed. FDG-PET was performed in 239 patients during the interictal period (no seizures for more than 24 hours). FDG-PET images were assessed visually and using statistical parametric mapping analyses, as described previously.¹³ Ictal and interictal SPECT was performed in 162 patients. Side-by-side visual analysis of interictal and ictal images and a subtraction method were performed using an approach described previously. The results of functional neuroimaging studies were defined as 'ipsilateral' if the predominant hypometabolic zone (FDG-PET) or the predominant hyperperfusion area (ictal-interictal SPECT) was concordant to one hemisphere including the epileptogenic lobe.

Epilepsy surgery

Patients underwent the appropriate surgery, which was performed by one neurosurgeon about 1 to 2 weeks after intracranial EEG monitoring. The extent of resection was determined by considering visible MRI lesions, the localization of ictal onset, interictal spikes, persistent pathological slowing on intracranial electrodes, and functional brain areas elicited by electrical stimulation.

Outcome and statistical analysis

We analyzed the relationship between the presence of aura and various factors such as demographic factors, duration of epilepsy, seizure frequency, epilepsy syndrome, the results of presurgical evaluations, and pathology. The relationship between SIA and the clinical factors was also analyzed. Student's *t*-test was used for continuous variables: age at operation, age at onset, epilepsy duration prior to surgery (defined by the difference between age at operation and age at onset), and seizure frequency per month before surgery. A chi-squared or Fisher's exact test of independence was used for univariate analysis, and multivariate regression analysis was used for multivariate analysis using the SPSS statistical package (SPSS ver. 19.0; IBM, Chicago, IL, USA). Surgical outcomes were classified according to the methods of Engel and colleagues.¹⁴ We evaluated the prognostic value of the patients' aura after epilepsy surgery. The prognostic value of SIA was also analyzed based on the degree of resection of areas with SIA. Moreover, we evaluated the relationship

between the area with SIA and the intracranial irritative zone and the ictal onset zone.

Results

Patients

From 1995 to 2009, we performed epilepsy surgery on a total of 1,038 patients. Both invasive studies and surgery were performed on 408 patients. After excluding patients who met the exclusion criteria, a total of 300 patients were recruited into the study (Table 1), 37.3% of whom were female. The mean age at surgery was 28.8 years, and the mean duration of epilepsy was 14.92 years. The mean duration of the postoperative follow-up period was 99 months. The patients were classified into epilepsy syndromes based on the intracranial ictal onset zones and resected areas: 52 cases of medial temporal lobe epilepsy (mTLE; 17.3%), 94 cases of lateral TLE (lTLE; 31.3%), 79 cases of frontal lobe epilepsy (FLE; 26.3%), 34 cases of occipital lobe epilepsy (OLE; 11.3%), 26 cases of parietal lobe epilepsy (PLE; 8.7%), and 15 cases of multilobar epilepsy (5.0%). The types of surgery are listed in Table 1. The most common pathology was focal cortical dysplasia (56.6%), followed by hippocampal sclerosis plus another lesion (dual pathology, 18.8%), hippocampal sclerosis only (5.2%), benign tumor (4.5%), vascular malformation (1.4%), and other lesions (13.0%). The seizure-free rate after surgery (Engel class 1) was 61.3%.

Table 1. Types of epilepsy surgery

Type of surgery	Value
ATL+AH	79 (26.3)
ATL	23 (7.7)
ATL+O neocortical resection	13 (4.3)
ATL+AH+lesionectomy	8 (2.7)
Others	46 (15.3)
Lesionectomy	50 (16.7)
Neocortical resection	31 (10.3)
Frontal lobectomy	31 (10.3)
Occipital lobectomy	5 (1.7)
Parietal lobectomy	5 (1.7)
Temporo-occipital lobectomy	5 (1.7)
Corpus callosotomy	4 (1.3)
Total	300 (100.0)

Values are presented as number (%).

ATL, anterior temporal lobectomy; AH, amygdalohippocampectomy; O, occipital.

Table 2. Types of aura described by the patients

Aura classification	Value
Psychic	51 (22.7)
Emotional	39 (17.3)
Epigastric/abdominal	36 (16.0)
Visual	32 (14.2)
Vertiginous	26 (11.6)
Indescribable	24 (10.7)
Autonomic	24 (10.7)
Cephalic	21 (9.3)
Somatosensory	17 (7.6)
Auditory	10 (4.4)
Olfactory	5 (2.2)
Gustatory	1 (0.4)
Sexual	0 (0.0)
Emotional+psychic	8 (3.5)
Emotional+autonomic	6 (2.7)
Emotional+epigastric	5 (2.2)
Epigastric+psychic	5 (2.2)
Cephalic+autonomic	4 (1.8)
Two kinds of auras	53 (23.6)
Three kinds of auras	8 (3.6)

Values are presented as number (%).

Aura

Aura was reported in 225 patients (75.0%), among whom one type of aura was present in 164 patients (72.9%) and two or more auras were present in 61 patients (27.1%). The types of aura are listed in Table 2. The most common aura was the psychic type (22.7%), followed by emotional and epigastric aura. We compared clinical characteristics between patients with aura and those without aura. The mean age at seizure onset was significantly lower in the aura-positive group (Table 3). Regarding epilepsy syndromes, the patients with mTLE or OLE had a significantly higher chance of having aura. Ictal SPECT had a higher lateralizing value in patients with aura. Certain types of aura had a localizing value. Indescribable feeling was associated with ITLE. Somatosensory (PLE), visual (OLE), auditory (ITLE), epigastric/abdominal (TLE total), cephalic (FLE), and psychic (TLE total) auras also had a localizing value (Table 4).

The surgical prognostic value of aura was evaluated in the context of other clinical factors, including the results of presurgical evaluations (Table 5). The presence of aura, mTLE, hippocampal sclerosis on pathology, focal lesions on MRI, and ipsilateral abnormality of

Table 3. Clinical characteristics of the patients with aura (aura-positive patients) and of those without aura (aura-negative patients)

Clinical characteristic	Aura-negative patients (n=75)	Aura-positive patients (n=225)	p-value
Female	26 (34.7)	86 (38.2)	0.679
Mean age at seizure onset (years)	17.26	13.09	0.003
Mean age at surgery (years)	30.44	28.31	0.090
Mean epilepsy duration (years)	13.64	15.34	0.097
Mean preoperative seizure frequency/month	7.69	10.85	0.228
Preoperative 2GTCS present	58 (79.5)	170 (77.6)	0.87
Febrile seizure present	15 (22.1)	61 (27.9)	0.432
ILAE syndrome classification			
FLE	26 (34.7)	53 (23.6)	0.069
PLE	10 (13.3)	18 (8.0)	0.174
Medial TLE	7 (9.3)	45 (20)	0.035
Lateral TLE	25 (33.3)	69 (30.7)	0.669
OLE	3 (4.0)	31 (13.8)	0.020
Histology			
Hippocampal sclerosis	13 (18.1)	56 (25.9)	0.204
Dual pathology	8 (11.1)	46 (21.3)	0.430
Presurgical evaluation			
MRI lesion present	48 (64.9)	140 (63.1)	0.889
PET, ipsilateral abnormality (n=239)	49 (83.1)	149 (82.8)	1.000
Ictal SPECT, ipsilateral abnormality (n=162)	23 (71.9)	116 (89.2)	0.021

Values are presented as number (%).

2GTCS, secondarily generalized tonic clonic seizure; ILAE, international league against epilepsy; FLE, frontal lobe epilepsy; PLE, parietal lobe epilepsy; TLE, temporal lobe epilepsy; OLE, occipital lobe epilepsy; MRI, magnetic resonance imaging; PET, positron emission tomography; SPECT, single-photon emission computed tomography.

Table 4. Localizing value of aura (number of patients)

Aura	FLE (53)	PLE (18)	Medial TLE (45)	Lateral TLE (69)	TLE total (114)	OLE (31)	Multilobar_F-T (8)	Multilobar_others (3)
Indescribable	7	1	0	13*	13	2	1	0
Somatosensory	7	10*	1	0	1	0	1	1
Visual	4	2	6	4	10	15*	0	2
Auditory	0	0	0	9*	9*	0	1	0
Vertiginous	4	1	6	8	14	7	0	0
Olfactory	0	0	3	2	5	0	0	0
Gustatory	0	1	0	0	0	0	0	0
Epigastric/abdominal	3	2	10	14	24*	4	3	0
Cephalic	12*	3	1	4	5	1	1	0
Emotional	12	3	8	13	21	3	2	0
Psychic	7	0	16	21	37*	8	1	0
Autonomic	9	3	4	6	10	0	2	1

FLE, frontal lobe epilepsy; PLE, parietal lobe epilepsy; TLE, temporal lobe epilepsy; OLE, occipital lobe epilepsy; F-T, frontal+temporal. * $p < 0.05$.

Table 5. Clinical factors that were significantly associated with surgical outcome

	Engel class I (n=184)	Engel class II-IV (n=116)	p -value
Presence of aura	147 (79.9)	78 (67.2)	0.02
Auditory aura	3 (2)	7 (9)	0.035
ILAE syndrome classification			
Medial TLE	44 (23.9)	8 (6.9)	<0.0001
TLE	102 (55.4)	44 (37.9)	0.004
PLE	12 (6.5)	16 (13.8)	0.042
Multifocal	3 (1.6)	12 (10.3)	<0.0001
Histology			
Hippocampal sclerosis	56 (31.3)	13 (12.0)	<0.0001
Dual pathology	44 (24.4)	10 (9.3)	0.002
Presurgical evaluation			
MRI lesion present	132 (72.5)	56 (49.1)	<0.0001
PET, ipsilateral abnormality	137 (89)	61 (71.8)	0.001

Values are presented as number (%).

ILAE, international league against epilepsy; TLE, temporal lobe epilepsy; PLE, parietal lobe epilepsy; MRI, magnetic resonance imaging; PET, positron emission tomography.

FDG-PET were significantly correlated with seizure-free outcome after surgery. The presence of auditory aura, PLE, multifocal epilepsy, and dual pathology were clearly associated with a not-seizure-free outcome. Other factors, such as the results of ictal SPECT, presence of febrile convulsion, presence of other specific auras, or presence of secondarily generalized tonic clonic seizure (2GTCS), were not related to surgical prognosis. Multivariate analysis showed that the presence of auditory aura (odds ratio [OR], 0.185; $p=0.03$) and mul-

tifocal epilepsy (OR, 0.051; $p=0.016$) were associated with not-seizure-free outcome. The presence of hippocampal sclerosis (OR, 3.057; $p=0.042$) and lesion on MRI (OR, 3.037; $p=0.03$) indicated a seizure-free outcome.

Stimulation-induced aura

Extraoperative electrical stimulation was performed in 190 patients, 134 of whom had a history of habitual aura. The electrical

Table 6. Surgical prognosis of SIA and overlap between the area with SIA and the ictal onset and irritative zones

SIA (n=29)	Value	Class I	Class II-IV	p-value
Resection of SIA area				0.72
Complete	15 (55.6)	9 (52.9)	6 (60)	
Partial	4 (14.8)	3 (17.6)	1 (10)	
No resection	8 (29.6)	5 (29.4)	3 (30)	
Ictal onset zone				0.73
Concordant	5 (18.5)	3 (16.7)	2 (22.2)	
Early spreading area	16 (59.3)	11 (61.1)	5 (55.6)	
Distant location	6 (22.2)	4 (22.2)	2 (7.4)	
Irritative zone				1.00
Concordant	6 (22.2)	4 (22.2)	2 (22.2)	
Partial	12 (44.4)	8 (44.4)	4 (44.4)	
Distant location	9 (33.3)	6 (33.3)	3 (33.3)	

Values are presented as number (%).
SIA, stimulation-induced aura.

stimulation induced the patients' habitual aura in 29 of these 134 patients (21.6%). The most common aura evoked by electrical stimulation was visual aura (six patients, 20.7% of all evoked auras), followed by somatosensory (five patients), psychic (four patients), vertiginous (three patients), cephalic (three patients), indescribable (two patients), auditory (two patients), emotional (two patients), epigastric (one patient), and autonomic (one patient) auras. Intracranial electrical stimulation induced habitual aura in more than 30% of the patients with somatosensory aura (five out of 13 patients) or visual aura (six out of 19 patients).

Among the clinical factors examined, only OLE had a higher tendency for positive SIA (OR, 3.845; $p=0.015$). Nine out of 20 OLE patients had SIA. Other factors, such as the mean age at onset, age, surgery, various epileptic syndromes with the exception of OLE, pathology, the results of neuroimaging studies, the seizure frequency, or the presence of febrile convulsion and 2GTCS, were not related to the presence of SIA. Complete resection of the area with SIA was performed in 15 out of 29 patients (Table 6). The concordance of the SIA area with the intracranial ictal onset zone or the intracranial irritative zone was not significant regarding surgical prognosis.

Discussion

Our data demonstrated that the presence of aura was related to good surgical outcome, as assessed by univariate analysis. Aura has localizing and lateralizing value in predicting the epileptogenic zone.¹⁵⁻²¹ Its localizing value may be comparable to that of EEG or

neuroimaging.²² However, the relationship between the surgical prognosis and the presence of aura has been studied rarely. A study based on a small number of patients showed that auras detected on intracranial EEG monitoring usually had the same origin as did complex partial seizures and favorable prognostic significance after temporal lobectomy.²³ Furthermore, the surgical prognostic value of aura in the context of other presurgical evaluations has never been studied. Our results demonstrated that the presence of aura, as well as mTLE, hippocampal sclerosis on pathology, focal lesions on MRI, and ipsilateral abnormality on FDG-PET were significantly correlated with seizure-free outcome after surgery. However, a multivariate analysis did not demonstrate a positive relationship between the surgical prognosis and the presence of aura. The strong relationship observed between positive MRI lesions and hippocampal sclerosis might mask the other relationship. The true significance of aura regarding surgical outcome should be evaluated via the analysis of patients with negative MRI.

The good surgical prognosis of the presence of aura can be explained by its localizing value. Somatosensory, visual, auditory, epigastric/abdominal, cephalic, and psychic auras were valuable in the localization of epileptogenic foci. In our study, somatosensory aura was more specific to PLE (10 out of 20 patients). However, it was also observed in seven FLE patients. Auditory aura was associated almost exclusively with ITLE, as nine out of 10 patients with auditory aura had TLE (one had multifocal epilepsy that included temporal foci). However, vertiginous aura was observed in various epilepsy syndromes. Human vestibular symptoms were provoked by the elec-

trical stimulation of various cortices.⁸ Epigastric aura and psychic aura, which are regarded as limbic aura, were observed in both medial and ITLE.

Intracranial electrical stimulation induced habitual aura. In our study, it evoked habitual aura in 21.6% of the patients who had a history of habitual aura. One previous study²⁴ showed that electrical stimulation induced aura in more than half of the patients. In another study, electrical stimulation of the amygdala and hippocampus elicited gustatory hallucinations in seven out of 20 patients who had gustatory hallucinations as aura in habitual seizures.^{16,25} In our study, electrical stimulation was performed more frequently in the patients with other epilepsies than those with mTLE (data not shown); i.e., electrical stimulation was not performed in many mTLE patients. This finding might explain the relative low incidence of SIA observed here compared with that reported in another two studies and may explain in part the higher frequency of somatosensory or visual aura detected compared with SIA.

The significance of SIA regarding surgical prognosis has been studied rarely. A previous study demonstrated that the zone of SIA overlapped with the epileptogenic lesion in 12 out of 16 patients (75%), seizure-onset zones in 75% of the patients, and the irritative zone in 50% of the patients.²⁴ However, our results demonstrated that the resection of the area with SIA was not related to seizure-free outcome. This absence of correlation may be supported by the fact that the area with SIA did not necessarily coincide with the intracranial irritative zone or the ictal onset zone in our study.

The area with SIA was concordant with the very first ictal onset zone in five patients and the early ictal spreading area in 16 out of 27 patients. However, it was distantly located in six patients (29.6%), was totally included in the irritative zone only in six patients, and overlapped partially in 12 out of 27 patients. Although auras had the same origin as the complex partial seizures of the individual patients,²³ our results suggested that the habitual aura manifested itself as an ictal spreading rhythm and did not necessarily indicate the true ictal onset zone or the epileptogenic zone. At this point, it is important to remember that the aura is not produced by the epileptogenic area itself; rather, it is an expression of the activation of symptomatogenic zones.¹⁸ Sufficient coverage of the presumed epileptogenic zone located around the area that generated a specific aura, and interpretation of the findings in the context of other presurgical evaluations are necessary. Sometimes, discharge spreading to electrodes other than the stimulated electrodes may affect the results.²⁶ To exclude this effect, an electrode was regarded as producing habit-

ual aura by stimulation only if the habitual aura was evoked by electrical stimulation without spreading afterdischarges in certain electrodes.

Although the presence of aura was significantly associated with good surgical outcome, auditory aura was associated with poor surgical outcome. The contiguity of the auditory cortex with the language cortex in the left hemisphere may hamper the complete and sufficient resection of pathology, which may have led to the poor outcome observed after surgery. The complex anatomy of the peri-insular area might also have contributed to this result. Patients with mTLE or OLE had a significantly higher chance of having auras. The presence of various and frequent auras in patients with mTLE is well known.¹⁸ This could also be explained by the fact that, in comparison with the widespread silent area of the frontal or parietal areas, the occipital lobe is closely related to visual function. Ictal-interictal SPECT had a higher lateralizing value in patients with auras. A radio tracer could be injected more at the earlier part of a seizure before the ictal rhythm spreads widely in patients with auras. We used an automatic injector that delivered the radioligand automatically when the patient felt aura. The use of this technique may shorten the injection delay further and improve the results of ictal SPECT.

Our study showed that the presence of aura favors good surgical outcome and that certain types of aura, such as auditory aura, have poor prognostic value. SIA, which was elicited in 21.6% of the patients, was not related to seizure-free outcome and did not necessarily coincide with the intracranial irritative or ictal onset zone.

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