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Atypical language cortex in. the left temporal lobe

Relationship to bilateral language

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Abstract *Background:* The intracarotid amobarbital procedure (IAP) is widely used in the preoperative evaluation for epilepsy surgery to lateralize language dominance and memory functions. However, language mapping has most often been accomplished with cortical brain stimulation. *Objective:* To examine left temporal lobe language cortex representation using this technique in patients with bilateral language (BL) as compared with patients with left language dominance (LD). *Methods:* The language maps of each patient were reviewed retrospectively. Group I consisted of 10 patients with BL and Group II consisted of 10 matched-control patients with LD: Each stimulation trial included a brief assessment of confrontation naming, automatic speech, reading, repetition, and comprehension. Clusters of errors that included comprehension, repetition, and naming defined primary temporal lobe language areas. *Results:* Mapping revealed two distinct - language areas in 60% of patients in Group I and 10% in Group II (p = 0.019). In. Group I, two patients had both language areas in the same gyrus (either the superior or the middle temporal gyrus), whereas two showed one language area each in the superior and middle temporal gyri and the remaining two had one in the superior temporal gyrus and the other intermixed between the superior and middle temporal gyri. In Group II, both language areas were intermixed between the superior and middle temporal gyri. *Conclusions:* Bilateral language (BL) representation in the intracarotid amobarbital procedure is frequently associated with more than one noncontiguous language area in the left temporal lobe. A careful search for multiple language areas, particularly in patients with BL, is prudent prior to surgical resection.

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Temporal lobectomy is a recognized' therapeutic procedure for medically intractable partial epilepsy arising from the temporal lobe.' The ultimate goal is to achieve complete seizure control[2,3] and to avoid surgical resection of eloquent cortex.[4] Surgical implantation of subdural electrode arrays (SEAs) is the currently recognized invasive technique utilized to map language functions and to identify the epileptogenic region. Penfield et al.[5,6] originally studied language area configurations using , electrocortical stimulation, performed intraoperatively in the left dominant hemisphere. Their findings led to the de- 'scription of three major language areas: 1) The Broca area is typically located in the third convolution of the inferior frontal lobe; 2) the Wernicke area occupies the posterior aspects of the superior, middle, and inferior temporal gyri as well as the supramarginal and angular gyri; 3) the supplementary language area lies on the medial aspect of the hemisphere, extending up to the superior surface, just in front of the preceritral leg area.' Since these early studies, other authors have evoked a widespread distribution of naming errors, in the lateral cortex of the dominant hemisphere, beyond the traditional language areas previously described.'-" In addition, these authors emphasized that the temporal lobe has a storage role for words, whereas the frontal lobe has a retrieval role for words or syntactic structure.' Recently, a new left basal temporal lobe language area has been described,'[2]-'[4] although there is no evidence that resection of this region results in dysphasia."'

Language representation in patients with bilateral language (BL) remains speculative: This casecontrol study is a retrospective analysis comparing temporal language areas in the left hemisphere in patients with BL with those in patients with left language dominance (LD).

Materials and methods. The medical records of 10 patients with BL (Group I) between January 1994 and December 2002 were reviewed from the institutionalized database at the Minnesota Epilepsy Group. A group of 10 LD patients (Group II) matched for age, gender, and brain pathology were selected for control.

Data retrieved consisted of age at cortical mapping, age at seizure onset, gender, handedness, seizure type, seizure frequency per month before and after surgery, seizure etiology based on the MRI findings, number of antiepileptic agents used before and after surgery, ictal and interictal EEG recording before surgery, pathologic results, and surgical outcomes. All patients underwent neuropsychological assessment pre- and postoperatively. Comparison of means for age at mapping and seizure onset between both groups was performed using t-test analyses.

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Table 1 Baseline information for 10 patients with bilateral - language based on IAP (Group I) as compared with 10 patients with left language dominance (Group II) -

Factor	Group I	Group II	p
Total no. of patients	10	. 10	
Mean age at mapping (SD), y	**23.6** (11.8)	24.2 (11.5)	0.58
Range of ages at mapping, y	7-44	12-43	
Mean age at seizure onset (SD), y	10.6 (8.5)	10.7 (8.6)	0.97
Range of ages at seizure onset, y	Birth-24	3-28	
M/F ratio	5/5	5/5	
R/L handedness	8/2	8/2	
CPS (seizure type)	10/10	10/10	
Seizure etiology"'			
MTS	7/10	5/10	
Unilateral (lefty	6/10	.5/10	
Bilateral	1/10	0/10	
Tumor	2/10	2/10	
Cryptogenic	1/10	3/10	
IAP	BL	LD	

* Seizure etiology based on the MRI of brain.

CPS = complex partial seizure; MTS = mesial temporal sclerosis; IAP = intracarotid amobarbital procedure; BL = bilateral language; LD = left language dominance.

Demographic data comparing both groups are shown in table 1.Male/female sex ratio was one to one in Groups I and II. Mean age at brain mapping,was 23.6 years (SD = 11.8 years) in Group I and 24.2 years (11.5 years) in, Group II (p = 0.58). Mean age at seizure onset was 10.6 years (SD = 8.5) in Group I and 10.7 years (SD. = 8.6 years) in Group II (p = 0.97). Eighty percent of patients were right handed and 20% were left handed.in Group's I and II. All patients presented with complex partial seizures.

The criteria for BL in our center include evidence of language function in at least one modality following injection of amobarbital into each hemisphere. Language responses must occur prior to the onset of contralateral motor recovery to be considered in the classification of language dominance. With use of this method, aphas a 'ollowing both injections is not considered adequate evidence of BL ·because the absence of language responses may occur secondary to confusion; obtundation, or behavioral factors unrelated to language dominance.[15] Patients were considered to have LD if they performed language tasks accurately following right'carotid amobarbital injection and were globally aphasic following left injection.

All patients had undergone an initial craniotomy over the left hemisphere for placement of SEAs and were subsequently monitored in the epilepsy unit. MRI was performed following SEA implantation to verify placement. EEG telemetry (64-channel recording system; Grass Telefactor, Quincy, MA) for seizure recording and electrocortical stimulation for language mapping were then conducted in the patient's hospital room. The stimulator used (model S12; Grass) consisted of a constant current of a- biphasic square waveform pulse with 0.5-millisecond pulse widths at 50 Hz of frequency. Current intensity varied between 2.5 and 17.5 mA. The stimulation was delivered to the cortex through platinum/iridium electrode pairs embedded in Silastic (model Radionics, Burlington, MA, or Adtech, Racine, WI). Stimulation was delivered to the cortex between two adjacent electrodes in multiple combinations. Concomitantly, after-discharges were monitored with each stimulation trial. Current levels used were determined to be just below the threshold for after-discharge responses to minimize seizure production during stimulation. Each language map was based on at least two stimulation, sessions.

The language protocol for each stimulation trial included tasks of automatic speech (counting), confrontation naming in response to drawings of common objects, one-step commands (auditory comprehension), repetition of a short phrase, and reading ·single words.[15] Language items were administered in quick succession over an 8- to 12-second period. '

Electrode sites where stimulation resulted in a change in motar or sensory. functions .or language errors were noted. These findings were 'correlated anatomically using direct visual, assessmeat of the color photograph taken during operation and the postoperative MRI. Nonparametric $x2$ analyses were used to study the findings between both groups' language maps. .

After completion of independent mapping trials by two epileptologists and one neuropsychologist, the appropriate resectable area of epileptogenesis in the temporal lobe to avoid the defined functional eloquent cortex was determined.

Results. *Diagnostic findings.* The .MRI findings for Group I revealed left mesial temporal sclerosis (MTS) in 70%, bilateral MTS in 10%, temporal tumor in 20%, and no abnormality in 10% (see table 1). In Group II; MRI. showed left MTS in 50%, temporal tumor in 20%, and normal , findings in 30%. In Group I, the tumor involved the middle temporal lobe in one patient and the mesial structures in the other. In Group II, one patient had the tumor in the anterolateral temporal lobe and the other in the posterolateral temporal lobe. In Group I, the EEG results indicated that the epileptiform discharge in ictal recordings originated from the left temporal lobe in 70%, the bilateral temporal lobes in 20%, and the left central region in 10%. In interictal recordings, 80% of the patients had the discharges from the temporal lobe, 10% from the bilateral temporal lobes, and 10% showed no interictal abnormality (table 2). In Group II, both ictal and interictal abnormalities originated from left temporal lobe in all cases.

Pathologic results. In both groups, pathology revealed neuronal loss and gliosis of the left hippocanipus consistent with left MTS in 80% of the cases. Of the remaining 20%, which were tumor cases, one had an oligodendroglioma grade II and the other had a ganglioglioma in each group.

Surgical procedures and outcomes. The tumor patients underwent debulking resection and the other cases had anterior temporal lobectomy.with resection of the mesial structures, at least 1 cm anterior to all language areas identified, in both groups. The mean seizure reduction frequency per month and the mean reduction in number of antiepileptic agents, before and after surgery, were significant in both groups (table 3). In Group I, 80% of the patients were seizure-free for at least 1 year following surgery, and the remaining patients had >75% reduction after surgery. One patient developed a thalamic infarct postoperatively. In Group II, 60% were seizure-free, 20% had seizure reduction in >50%, and the remaining 20% had no 'seizure reduction. The, mean Full-Scale IQ was in the average range for both groups preoperatively and did not decline , significantly following. surgery (see table 3). None was clinically aphasic postoperatively, and formal assessment for aphasia was not conducted.

Language localization. Language mapping revealed the presence of two distinct language areas in the left temporal lobe in 60% of the patients in Group I and in 10% of the patients in Group II. Nonparametric X2 analyses revealed an association ($x^2[1, n = 20]$.= 5.50, p = 0.019) between the language dominance and the number of language areas found. When two language areas were identi-

*Table **2** Surface EEG recording, MRI, SPECT, and PET results before surgery, type of surgery, and seizure outcomes after surgery for 10 patients with bilateral language based on IAP*

Patient *no.*	Ictal	Interictal	MRI	SPECT	PET	Surgery	Seizure*
1	L temp	. L temp	L MTS	L MTS	N/A	ATL + MSR	Free
2	L temp	L temp	L MTS	' N/A	N/A	ATL + MSR	Free
3 .	Bil temp	Bil temp	L MTS	L MTS	L tempt	ATL + MSR	Free
• 4	L temp	L temp	L.MTS	Bil MTS	N/A	ATL + MSR	Free
5	Bil temp	L.temp	Bil MTS	L MTS	N/A	ATL + MSR	Reduction$
6	L central	Normal	L MTS .	N/A	L tempt	ATL + MSR	Free
7	L temp	L temp	Normal	N/A	N/A	ATL + MSR	Free.
8	L temp	L temp	L MTS	N/A	N/A	,ATL + MSR	Free
9	L temp	L temp	L middle temp tumor	N/A'	N/A	Debulking	Free
10	L temp	L temp	L mesial structure tumor	N/A	N/A	Debulking	Reduction$

* Seizure outcome for 1-year follow-up. t Left temporal hypometabolism. $ >75% reduction.

IAP = intracarotid.amobarbital procedure; MTS = mesial temporal sclerosis; N/A = not applicable; ATL + MSR = anterior temporal lobectomy and mesial structure resection; temp ='temporal; BE = bilateral.

fled, an•area of silent cortex always separated them (figure 1). All language areas were defined by consistent errors of ' comprehension, repetition, and naming in response to stimulation.

They were located not only in the superior temporal gyrus but also in -the middle temporal gyrus or intermixed between the superior and middle temporal gyri. In fact, in Group I, two patients were found to have both language areas in the same temporal gyros: In the first patient, this was in the superior temporal gyrus (figure 2A); however, the second patient had two language areas in the middle temporal gyrus (see figure 2B). In the four remaining patients, the two language areas were located in two different adjacent gyri; one of these language areas was found consistently in the superior temporal gyrus and the other was either in the middle temporal gyrus (in two patients) (see figure 2C) or intermixed between the superior and middle temporal gyri (in two patients) (see figure 2D). In Group II, 9 of 10 -patients had a single, isolated language area, and 1 patient demonstrated two language areas, which were intermixed between superior and middle temporal gyri.

All language areas were located between 3 and 9 cm from the left temporal tip in both groups. Only four pa-

, ***Table 3*** *Mean seizure frequency/ month, antiepileptic agents, and FSIQ variables before and after surgery of Group I and Group II*

Variable	Before surgery	After surgery	Reduction	SD	p Value
SF/mo					
Group I	10.5	0.4	10.1	7.7	0.003*
Group II	**5.3**	1.4	3.8	3.9	0.025*
Antiepileptic agents					
Group I	4.6	1.4	3.2	1.4	0.000*
Group II	4.4	1.8	2.6	1.3	0.001*
FSIQ					
Group I	90.5	91.6	1.1	7.6	0.66
Group II	101.4	97.7	3.7	13.3	0.49

* Significant.

FSIQ = Full-Scale IQ; SF/mo = seizure frequency/mo.

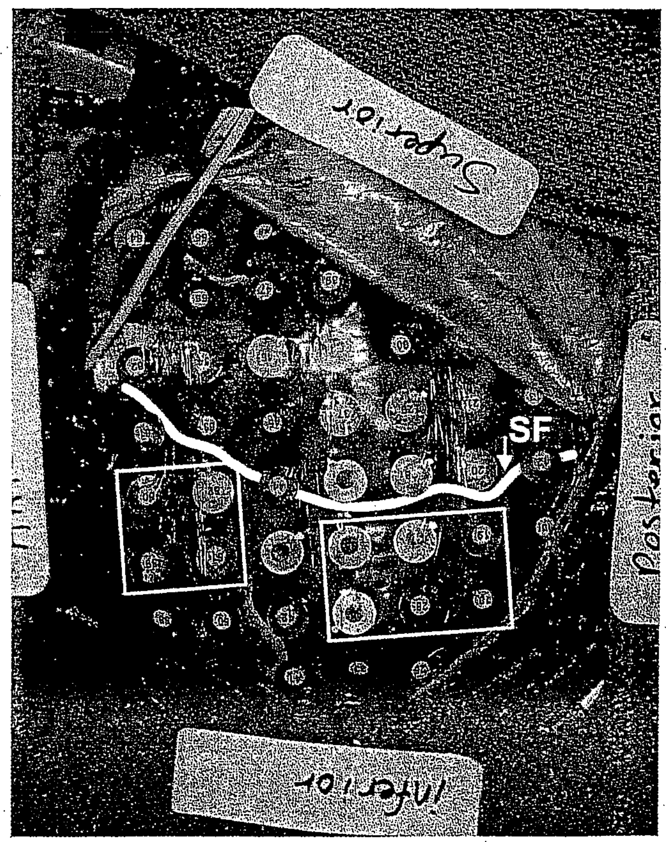

Figure I. Schematic representation of both language areas separated by a silent cortex on a direct photograph taken intraoperatively of an implanted subdural electrode array.

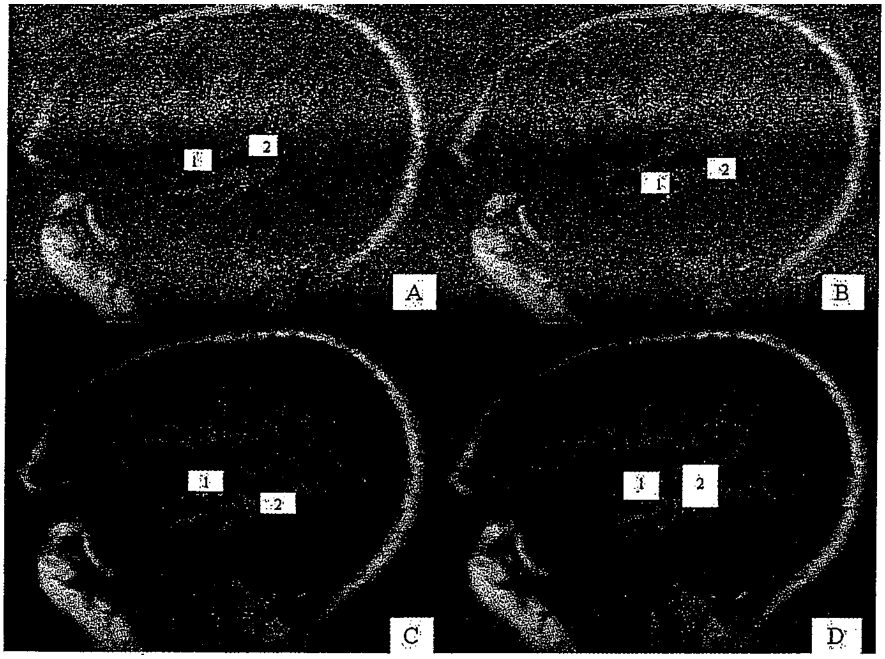

Figure 2. Reconstruction of the two distinct language areas identified by electrocortical language mapping over the left temporal lobe on a standard sagittal TZ-weighted MR template. '(A) Both located in the superior temporal gyrus. B) Both located in the middle temporal gyrus. (C) One located in the superior temporal gyrus and the other in the middle temporal gyrus. (D) One located in the superior temporal gyrus and the other intermixed between the superior temporal and middle temporal gyrus.

tients had a language area anterior to 5 cm (three -in Group I and. one in Group II).

The surface area of each language area found over the left temporal lobe in these patients ranged from a minimum of 2 x 1 cm2 to a maximum of 4 x 2 cm2 in both groups.

Random isolated single-site language errors were also identified beyond the margins of these two language areas over the left temporal lobe.

Discussion. Previous studies have emphasized the presence of a single language area in the posterior part of the dominant superior, middle, or inferior temporal gyrus in patients with unilateral hemispheric dominance for language.5[6] However, the configuration of the left temporal language areas, to our knowledge, has not been previously discussed in the literature in patients withBL representation. In this study, 60% of our patients with BL based on the intracarotid amobarbital procedure (TAP) and. 10% of patients with LD demonstrated two noncontiguous language areas separated by silent cortex. The association of duplicated language areas in the left temporal lobe with bilateral language classification was significant. The representation of these language areas is not predictable a priori over the left temporal lobe; they may be located in the same temporal gyrus or in two different gyri. Both language areas shared similar characteristics: They had quasi-equal dimensions and were defined by similar language errors.

The localization of these language areas was basically noticed in the posterior part of the left temporal gyros, as- described by Wernicke.[5] Nevertheless, in Group I, three of the language areas were found to be located anterior to 5. cm from the temporal tip,"as well as in one patient in Group II, consistent with some previous reports.[16,17]

As discussed in previous studies,[%il] isolated sites were identified at which a single language error was produced. These sites were typically located anterior to identified language areas, and their resection did not lead to aphasic symptoms postoperatively.

None of the cortical language areas identified was surgically resected in this series, and therefore the clinical significance of these language areas remains uncertain. We' have assumed that it is necessary to avoid their resection given their configurations and the recorded responses. during language mapping.

As language cortex. can. be identified only in the, human brain, there is no animal model appropriate for the study of cortical language organization. Hence, observations should be based on cortical brain mapping in patients requiring temporal resection to further investigate and substantiate our knowledge about cortical language distribution. These findings do not provide any information on the duplication of language in the right hemisphere beyond the information obtained in the TAP. Therefore, further study of the right hemisphere in patients with BL requiring invasive ' or noninvasive techniques using perhaps functional MRI or magneto-EEG is needed for further clarification. Our results were based on a retrospective case-rorfrr1ipd Analysis representing *a 9-yew*· pt:1 loci of expenence in our center. We intend in the future to evaluate these patients. prospectively comparing SEA data with those from other noninvasive methods to confirm our observations.

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