CASE REPORT

Right Hemisphere Language Dominance in a Right-Handed Patient with Late-Onset Seizures

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Right hemisphere language dominance is rare in right-handed individuals and usually the result of language transfer associated with early left hemisphere pathology. We studied a 33-year-old right-handed man, with a normal MRI scan, who developed left frontal lobe seizures at age 15 years. Language lateralization testing by intracarotid amobarbital injection and dichotic listening showed the patient to be strongly right hemisphere language dominant. The clinical features of this patient do not fit the profile of pathology-induced language transfer, but instead suggest that he was right hemisphere language dominant before developing seizures. This case underscores the importance of language lateralization testing in patients who are candidates for seizure surgery, even if they are strongly right-handed and have late-onset seizures, features usually associated with left hemisphere language dominance. One implication is that the incidence of right hemisphere language dominance in the right-handed population may be underestimated.

Key Words: right hemisphere language; language lateralization; late-onset seizures; epilepsy.

INTRODUCTION

It is well established that the prevalence of right hemisphere language dominance (RHLD) in neurologically normal right-handed individuals is rare. Estimates of RHLD in dextrals range from 0 to 2% and are based largely on the incidence of aphasia in patients with unilateral right hemisphere strokes and left hemiplegias (1–4). Because of the difficulty distinguishing patients who are exclusively right hemisphere language dominant from those with bilateral language representation, even such low estimates may be inflated (5). This view is supported by a recent functional MRI study that showed no evidence of exclusively right hemisphere activation or even right greater than left hemisphere activation in any of the 100 normal right-handed subjects studied (6).

The incidence of RHLD in patients with early brain injuries is known to be higher than that in the normal population (7, 8). It is estimated that 10 to 20% of patients who sustain left hemisphere lesions before age 5 years are right hemisphere language dominant (8). This is attributed to pathology-induced language transfer and is usually accompanied by a shift in handedness (9, 10).

Early-onset seizures of the left hemisphere are also associated with higher incidence of RHLD (8). One of the primary methods used to determine language lateralization in seizure patients is the intracarotid amobarbital injection (IAI). IAI temporarily deactivates the injected hemisphere, allowing direct testing of the language capabilities of the unaffected hemisphere (11).
Based on previous IAI studies, it is estimated that between 6 and 15% of right-handed patients with intractable seizures are right hemisphere language dominant (9, 10). Although a shift in handedness usually accompanies language transfer in patients with early-onset left hemisphere seizures, patients with chronic temporal lobe seizures appear to be less likely to transfer motor function due to sparing of left motor cortex (10).

Seizure disorders that develop after 10 years of age are thought to have little effect on language dominance since language lateralization is considered largely complete by 5 to 10 years of age (12, 13). However, a recent functional MRI study reports evidence of bilateral language activation in 13% of patients studied with late-onset seizures (6). This suggests that late-onset seizure disorders may affect language lateralization, although to a lesser extent than early-onset seizures. Hence, it is still considered unlikely that patients with late onset left hemisphere seizures could be exclusively right hemisphere language dominant.

We studied a strongly right-handed adult patient with late-onset seizures who was exclusively right hemisphere language dominant on two independent tests of language lateralization. This case is notable because it does not fit the traditional profile of pathology-induced language transfer and suggests that the prevalence of RHLD in right-handed individuals may be underestimated.

**PATIENT**

The patient is a 33-year-old right-handed man who developed seizures at age 15 years. There were no prenatal or birth complications, no early brain injury, and no family history of seizures or left-handedness. Language development was normal, and the patient met all developmental milestones. He completed 14 years of education, with an associate’s degree in horticulture. At the time of testing, the patient had one to three complex partial seizures a month, lasting approximately 30 seconds each, that were characterized by abrupt loss of consciousness and ictal features of staring, confusion, and occasional automatisms. The patient had secondarily generalized tonic–clonic seizures approximately twice per year. Ictal scalp EEG recordings identified a left frontal lobe seizure focus. MRI spectroscopy suggested a possible area of metabolic abnormality (NAA) in the left frontal lobe and insula. Previous medications included carbamazepine, phenytoin, phenobarbital, and valproate, none of which, alone or in combination, provided measurable seizure control. At the time of testing, his medications included phenytoin (400 mg daily) and lamotrigine (600 mg daily).

The patient was referred as a candidate for resection surgery. MRI scans performed as part of the presurgery evaluation revealed no cortical abnormalities and no evidence of mesial temporal sclerosis. Neuropsychological evaluation showed low average verbal intelligence, with a borderline Full-Scale IQ of 74 (verbal IQ = 79, performance IQ = 70) on the WAIS-R (14). The patient was impaired on tests of new verbal learning. His auditory digit span score was in the low average range (9th percentile). Long-term visual memory, using the Rey–Osterreith complex figure, was in the low average range (21st percentile). The patient obtained a score of 28/30 on the Mini-Mental Status Exam (15). Visual–spatial abilities, as measured by block design, were in the low average range (9th percentile). Psychomotor speed and dexterity were impaired for both the dominant (right) and nondominant hand. Results of a hearing test showed normal thresholds bilaterally (250–8000 Hz) with excellent word recognition.

The patient’s handedness was verified by use of his right hand during a writing task, by self-report of hand use during daily activities, and by parental interview, which confirmed evidence of right-handedness from early childhood. The patient provided informed consent for all testing.

**METHODS AND RESULTS**

Language lateralization was determined clinically by consecutive IAI’s. Each hemisphere was perfused separately with 125 mg of amobarbital injected into the internal carotid artery via a transfemoral catheter. No filling of the posterior cerebral arteries or cross-filling of the anterior cerebral arteries occurred with either injection. Language testing was initiated after loss of contralateral limb strength and onset of unilateral EEG slowing. Language tests included object naming (N = 6), auditory word discrimination (N = 4), picture–word matching (N = 4), and word reading (N = 4). Expressive language abilities were assessed by object naming and oral word reading, while receptive language was assessed by auditory word discrimination and picture–word matching (16, 17). A small number of stimuli were used to ensure sufficient time to assess multiple language functions during the pe-
TABLE 1
Results of IAI Testing Represented as Number of Correct Responses

<table>
<thead>
<tr>
<th>Task</th>
<th>Right injection</th>
<th>Left injection</th>
</tr>
</thead>
<tbody>
<tr>
<td>Object naming</td>
<td>3/6</td>
<td>5/6</td>
</tr>
<tr>
<td>Picture–word matching</td>
<td>3/4</td>
<td>4/4</td>
</tr>
<tr>
<td>Auditory word</td>
<td>1/4</td>
<td>4/4</td>
</tr>
<tr>
<td>Word reading</td>
<td>1/2</td>
<td>2/2</td>
</tr>
</tbody>
</table>

rior period of drug activation. Motor strength was assessed after each task to ensure continued amobarbital effects. IAI results are considered uninterpretable once contralateral motor functions return by ≥50% and/or the EEG slowing dissipates (9, 16).

Injection of the right hemisphere resulted in significant impairment of receptive and expressive language functions, lasting until the return of contralateral motor function and dissipation of unilateral EEG slowing. Specifically, the patient made errors ($\bar{x} = 2$) on every language task (Table 1). Errors were identified by comparison with the patient’s flawless baseline performance 1 day earlier, when he was tested on comparable stimuli that were matched for frequency and length. Following the left injection and subsequent loss of contralateral limb strength, the patient made a single error on only one language task (object naming). Based on previously published criteria for interpretation of IAI test results, these findings were interpreted clinically as indicating that the patient was strongly right hemisphere language dominant (9, 17).

Language lateralization was assessed behaviorally by tests of dichotic listening. This testing was performed the day of admission for surgery, 1 week after the IAI procedure. Dichotic listening involves simultaneous presentation of two different auditory stimuli to each ear. The listener is instructed to repeat both items, in a specified order (e.g., right ear first). It is well established that stimuli presented to the ear contralateral to the language-dominant hemisphere are repeated with greater accuracy and that most righthanded subjects show a right ear advantage for speech (18). Our patient completed two dichotic listening tasks: the competing words and competing sentences subtests of the SCAN-A (19). When asked to repeat right ear stimuli first, he was able to correctly repeat only 6 of 15 monosyllabic words (e.g., feet, day) as compared with 13 of 15 words presented dichotically to the left ear. When the order of response ear was reversed (left ear first), he correctly repeated 14 of 15 words presented to the left ear as compared with 8 of 15 right ear words. The magnitude of the left ear advantage was highly significant, occurring in less than 2% of the general population. On the competing sentences subtest, two sentences of four to six words each are presented dichotically. The listener is asked to repeat only sentences presented to one ear. The patient correctly repeated all ten sentences presented dichotically to his left ear and only one of the ten sentences presented dichotically to his right ear. Evidence of a significant left ear advantage is consistent with RHLD, corroborating the IAI test results.

To further localize the patient’s seizures, a craniotomy was performed to implant a $6 \times 8$ electrode array in the subdural space over the left dorsolateral surface of the frontal lobe and anterior parietal lobe (Fig. 1). Two additional $1 \times 4$ electrode strips were placed across the orbital frontal region. Electrodes were composed of platinum–iridium disks that are 2.3 mm in exposed diameter, spaced 10 mm apart in a medical-grade Silastic polymeric silicone (Adtech Corp., Racine, WI). Electrode locations were determined from intraoperative photographs, CT scans, and a three-dimensional (3D) MRI scan with coregistration of electrode locations from 3D CT scans (Fig. 1). The composition of the two orbital frontal electrode strips did not permit viewing on MRI or CT scan. The subdural electrodes were present for 7 days, during which time 24-hour EEG recordings were made and motor functions were mapped extraoperatively by electrical interference.

EEG recordings localized the foci of four seizures to six electrode sites located in the anterior superior frontal lobe (Fig. 1). Mapping of motor functions was performed extraoperatively by direct cortical electrical interference, also known as cortical stimulation. This clinical technique is used routinely to map motor, language, and visuospatial functions in epilepsy patients for planning of resection surgery (20–24). Electrical interference was produced by generating a 300-microsecond square-wave pulse of alternating polarity at a rate of 50 pulses per second, for 5-second intervals, between pairs of adjacent electrodes. A testing threshold of 11 to 15 mA was attained in 0.5-mA increments. Trials with afterdischarges (<2%) were excluded from analysis. Motor functions were tested at all electrode sites. We tested four motor functions: (1) horizontal eye tracking; (2) tongue movement (side-to-side); (3) bilateral finger movement (simulated piano playing); and (4) bilateral toe/foot movement. A deficit was defined if one or more of these motor functions was inhibited or if electrical interference induced movements (e.g., tongue retraction, fin-
Results of motor mapping are represented in Fig. 1 and are consistent with previous cortical stimulation and direct cortical recording studies (21, 25–27). Motor functions were mapped to electrode sites in the anterior frontal lobe, immediately adjacent to the patient's seizure focus. We also tested speech functions at electrode sites where no motor deficits were induced. Language testing included word reading, picture naming, and auditory comprehension, as assessed by the Token test (28). No language deficits were induced, despite the location of electrode sites in classic Broca's area. This is consistent with results of the IAI testing and dichotic listening studies that showed the patient to be strongly right hemisphere language dominant. Seven days after subdural grid implantation, the patient underwent electrode removal and left anterior frontal lobe resection through the original craniotomy site. Neuropsychological testing 1 month after surgical resection revealed no language or cognitive deficits. Pathological examination of the resected left frontal lobe tissue, including immunohistochemistry, showed evidence of gliosis and mild chronic inflammation of the meninges, the latter being consistent with the patient's history of electrode implantation. No other abnormalities were noted.

**DISCUSSION**

On initial examination, there were no indicators that our patient had atypical language dominance. Specifically, he was strongly right-handed in his daily activities, with no history of early brain injury and no family history of left-handedness. Although he had chronic epilepsy, he was not expected to be right hemisphere language dominant because his seizures did not begin until 15 years of age, after language lateralization is considered complete and neural plasticity is reduced (12, 13). Two independent tests of language lateralization, however, showed the patient to be strongly right hemisphere language dominant. Results of IAI testing indicated that he was entirely right hemisphere language dominant, with no evidence of left hemisphere language representation. This was supported by the highly significant left ear advantage elicited on tests of dichotic listening and also by results of cortical stimulation testing, which failed to induce language deficits in left frontal lobe areas typically associated with language function.

We consider two possible explanations for these findings. One possibility is that RHLD was acquired in...
our patient as a function of pathology-induced language transfer without a shift in handedness. Most cases of language transfer, however, are initiated by brain injuries sustained before 5 years of age and are accompanied by a shift in handedness (7–9). Our patient had a normal MRI scan, had no history of early brain injury, and showed no evidence of shifting to left-handedness. Our patient did not develop seizures until age 15 years and remained strongly right-handed. It has recently been suggested that late-onset seizures can affect language lateralization, although not to the same extent as early-onset seizures, resulting in an increased incidence of bilateral language representation (6). Results of IAI testing, however, showed no evidence of bilateral language representation. Our patient was exclusively right hemisphere language dominant on receptive and expressive language measures.

It may be argued that underlying neuropathology may have predated the onset of his seizures and induced language development in the right hemisphere. The presence of mesial temporal sclerosis has been associated with language transfer in patients who develop early seizure disorders (10). Our patient showed no evidence, however, of mesial temporal sclerosis or other abnormalities on his MRI scans. Nevertheless, it is possible that an abnormality not evident on MRI may have predated the onset of the patient’s seizures. However, even if our patient’s RHLD could be attributed to language transfer, it would be difficult to explain the absence of a corresponding shift in handedness. Language transfer without a shift in handedness appears to be limited largely to patients with temporal lobe seizures where there is no proximity to motor areas. Conversely, our patient’s seizure focus was in the anterior frontal lobe, adjacent to motor areas (Fig. 1), which should increase the likelihood that a transfer of language would be accompanied by a shift in handedness. In summary, there are converging lines of evidence challenging the view that our patient’s RHLD is the result of pathology-induced language transfer.

A second explanation is that our patient developed language in the right hemisphere from birth. It is currently estimated that between 0 and 2% of the right-handed population is exclusively right hemisphere language dominant. This estimate is based on studies of right-handed patients who develop aphasia subsequent to unilateral right hemisphere stroke lesions (1–4). It has been argued that even this low incidence may be overestimated because of the difficulty distinguishing those stroke patients who have bilateral language representation from those who are exclusively right hemisphere language dominant (5). Results of IAI testing with our patient showed no evidence of bilateral language representation. Our data are largely consistent, therefore, with the view that this patient developed language in the right hemisphere before the onset of his seizure disorder. The absence of aphasia that is occasionally observed in right-handed patients with large left hemisphere lesions and right hemiplegias supports the possibility of premorbid RHLD (29).

This case underscores the importance of language lateralization testing in patients who are candidates for seizure surgery, including those who are strongly right-handed, have late-onset seizures, and have no history of early left hemisphere injury. Evidence of premorbid RHLD in this patient also suggests that the incidence of exclusive RHLD in the neurologically normal population may be underestimated.

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