Evidence of a large-scale network underlying language switching: a brain stimulation study

Case report

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This 47-year-old, right-handed bilingual (French and English) man underwent awake surgery for a glioma in the left dominant posterior temporal lobe. During intraoperative picture naming, direct electrostimulation of a discrete cortical area within the posterior part of the superior temporal sulcus elicited an involuntary language switching (French to English). Moreover, during tumor resection, subcortical electrical mapping again generated reproducible language switching (French to English) when stimulating the superior longitudinal fasciculus. After transient immediately postoperative worsening, the patient recovered normal language performance. Both 7 days and 2 months later, however, another language switching episode (French to English) was observed during a naming task. Thus, both intraoperative mapping and transient postsurgical disturbances support involvement of the left dominant posterior temporal area and the superior longitudinal fasciculus in language switching. Interestingly, this pathway is known to connect the posterosuperior temporal gyrus to the Broca center, a region the authors have described as inducing possible switching on stimulation. Therefore, the authors suggest the existence of a large-scale distributed network subserving language switching. Such knowledge may have important clinical implications for the surgical care of a bilingual patient harboring a lesion in the left hemisphere. (DOI: 10.3171/2009.4.JNS081587)

KEY WORDS • bilingualism • intraoperative electrical stimulation • language switching • anatomofunctional connectivity • awake mapping • superior longitudinal fasciculus

Although the neural basis of bilingualism has been extensively analyzed using lesion studies, functional imaging, and brain stimulation mapping,8,9 the functional anatomy underlying language switching has received less attention.7 Very few functional neuroimaging10,15 and transcranial magnetic stimulation studies11 have suggested the participation of the left dorsolateral prefrontal cortex, left inferior area, and supramarginal gyrus during switching between different languages. More recently, we reported the case of a patient who switched from French to Chinese during intraoperative electrocortical stimulation of the left inferior frontal gyrus.12 Using the Wada test, we concluded that involuntary switching was the result of a temporary disruption of brain areas involved in language switching.12 As far as we know, however, there are no currently available data about the subcortical connectivity underlying such a mechanism.

Here, we report the case of a 47-year-old, right-handed bilingual (French and English) man who underwent awake surgery for a glioma in the left dominant posterior temporal lobe. During intraoperative picture naming, direct electrostimulation of a discrete cortical area within the posterior portion of the superior temporal sulcus elicited unintentional language switching (French to English). Interestingly, during tumor resection, subcortical electrical mapping again generated reproducible language switching (French to English) on stimulation of the SLF. Therefore, we suggest the existence of a large-scale distributed network of language switching subserved by the SLF, a concept important to know during surgery for...
any lesion involving the left dominant hemisphere in bilingual patients.

Case Report

History and Examination. Seizures related to a left posterior temporal WHO Grade II glioma had developed 6 years previously in this 47-year-old, right-handed man. A first surgery without language mapping was performed at another institution while the patient was under general anesthesia. There was no postsurgical neurological worsening, but the resection was partial. Because of regrowth of a residual glioma, radiotherapy followed by chemotherapy was administered. After transient stabilization, a new increase in the residual glioma volume was seen on repeat MR imaging, with enhancement located around the posterior part of the superior temporal sulcus (Fig. 1A). Moreover, the patient experienced new seizures. At that time, he was referred to our institution for a second surgery.

He was a bilingual (French and English) French medical doctor, with normal findings on neurological examination. The Edinburgh inventory indicated that he was right handed.14 Language evaluation performed using the 86β version of the Montréal-Toulouse Aphasia Battery and the DO 80 (oral denomination 80) was normal except for rare semantic paraphasias and mild disorders of morphosyntactic comprehension. His English language proficiency was moderately good. He regularly communicated in English at work but not at home. No preoperative functional neuroimaging with respect to mapping of the 2 languages was performed.

Operation and Intraoperative Electrostimulation Mapping. Intraoperative cortical and subcortical functional mapping were performed in the patient under awake conditions, without the use of neuronavigation. We have extensively detailed this technique in previous reports.3–6 Briefly, a bipolar electrode with a 5-mm space between its tips and delivering a biphasic current (pulse frequency 60 Hz, single pulse phase duration 1 msec, and amplitude 3 mA; Nimbus, Hemodia) was applied to the brain. In the first stage of the surgery, cortical electrical mapping was performed to identify areas essential for language and to define the superficial boundaries of resection in the awake patient, who performed a picture-naming task (DO 80) preceded by a short sentence (the French translation of “this is a . . .”). Direct stimulation of a discrete cortical area located within the depth of the posterior part of the superior temporal sulcus (Fig. 1B Site 16) elicited a reproducible language switching (tested 3 times, with switching induced each time). The patient provided the correct name but suddenly in English, whereas all the other pictures were named in French. At the end of stimulation, he resumed naming in French. In addition to this area, another language site was found within the posterior-temporal region, close to but distinct from the “switching area,” eliciting reproducible (3 times on 3 stimulations) semantic paraphasias during stimulation.

After cortical mapping was completed, resection was performed according to corticosubcortical functional (language) boundaries.3–6 During this second stage of surgery, the subcortical level was directly stimulated to identify the white matter language pathways. Interestingly, subcortical electrical mapping again generated reproducible language switching (French to English) on stimulating the white matter in the depth of the surgical cavity (Fig. 1B Sites 19 and 20). Stimulation of this tract also elicited phonemic paraphasias.

Postoperative Course. Immediately after surgery, the patient experienced transient aphasia with severe disorders of both speech expression and language comprehension. Language production was reduced to some words and automatisms together with anomaia as well as phonemic and semantic paraphasias. In addition, there were major disturbances in oral and written lexical as well as morphosyntactic comprehension.

Control MR imaging was performed immediately after surgery, showing complete tumor removal (Fig. 1C). This imaging study also enabled accurate analysis of the anatomical location of the subcortical language pathways at the periphery of the cavity, where the resection was stopped according to the functional response elicited by

![Image](image.png)
Language switching network

Intraoperative stimulation—a method of anatomofunctional correlation extensively validated in our previous reports.3–6 Thus, we determined that the tract preserved at the end of the resection and which induced language switching as well as phonemic paraphasias during stimulation was the SLF. Seven days after surgery, the patient recovered better speech production (despite some perseverations and phonemic paraphasias), and his comprehension improved. Another switching episode (French to English) was observed during a naming task (involving 10 of 80 items). The patient explained that the word spoken (in the language expressed) was the first word that had come to his mind.

The neuropathological examination revealed a high-grade glioma. A second line of chemotherapy was administered to the patient. After 2 months of specific language rehabilitation, the Montréal-Toulouse score was almost normal, although a slight deficit in morphosyntactic comprehension persisted. Again, a switching episode (French to English) occurred during the language assessment.

Discussion

To our knowledge, this case is the first reported instance of transient, reproducible language switching elicited by direct intraoperative stimulation of the posterior part of the left dominant superior temporal sulcus as well as its underlying axonal connectivity. Given that the stimulated fibers were located under the posterosuperior temporal gyrus (the so-called Wernicke center), as demonstrated by intraoperative mapping as well as postsurgical MR imaging, the SLF likely represents these fibers. Indeed, even if diffusion tensor imaging was not performed, it was possible to determine that this pathway was actually the SLF on the basis of 2 reliable facts: 1) its stimulation also generated phonemic paraphasia—a typical symptom during stimulation or lesioning of the SLF;2 and 2) postoperative MR imaging combined with intraoperative data enabled us to perform anatomofunctional correlations by using a previously validated method.3–4 Anatomically, this pathway is well known to connect the posterosuperior temporal gyrus to the inferior frontal gyrus.1 Interestingly, stimulation of these 2 cortical areas can also elicit language switching. Indeed, we have already described the case of a patient in whom intraoperative cortical electrostimulation over the Broca center generated a transient unintentional switching from French to Chinese.12 We suggested that stimulation induced a temporary disruption of an "epicenter" involved in language switching. This observation agrees with previous transcranial magnetic stimulation,4 functional neuroimaging,14,15 and lesion studies supporting involvement of the left frontal lobe in switching. In the present case we induced transient involuntary language switching by stimulating a discrete area within the posterior part of the left superior temporal sulcus. Considering that this region is connected to the Broca center by the SLF, which also generated reproducible switching during its stimulation, we argue that language switching is actually subserved by a large-scale corticosubcortical network rather than by a single area.

Furthermore, it has been shown by using both diffusion tensor imaging4,13 and intraoperative subcortical stimulation1,5 that the SLF consists of different components: 1) a deep part corresponding to the classic arcuate fasciculus—here identified by stimulation since it also induced phonemic paraphasia2 and which directly connects the posterosuperior temporal area with the inferior frontal cortex—and 2) a more lateral component that creates a relay at the level of the supramarginal gyrus. Although we did not perform extensive mapping of the inferior parietal lobule in our patient (because the tumor was located in the temporal lobe), it is nevertheless worth noting that activation of the left supramarginal gyrus during switching had already been reported with functional neuroimaging.10,15 As a consequence, we hypothesize that the distributed network underlying language switching is much more complex than a single, direct temporofrontal connection.

Conclusions

In summary, the virtual and reversible lesions made by transient cortical and subcortical stimulation indicate that, in addition to the left inferior frontal gyrus, the left dominant posterosuperior temporal cortex and SLF are critically involved in language switching. The transient switching that occurs after surgery strongly supports this hypothesis, given that the resection was continued until corticosubcortical functional structures were encountered—also explaining the transitory worsening of language performance. Thus, results in the present study provide new insights into the anatomo-functional connectivity subserving the wide network involved in switching, by introducing a "connectionist view" rather than a "localizationist view" in accordance with the recently suggested concept of the hodological organization of language.2 In addition, such knowledge may have important clinical implications, especially for the surgical treatment of bilingual patients harboring a lesion within the left dominant hemisphere. However, we acknowledge that larger series of bilingual patients studied under the same circumstances are needed to confirm our preliminary data.

Disclaimer

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

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