LETTER TO THE EDITOR

Probabilistic map of language regions: challenge and implication

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Sir,

We have read the article entitled ‘Probabilistic map of critical functional regions of the human cerebral cortex: Broca’s area revisited’ by Tate et al. (2014) with great interest. In that article, the authors presented a bilateral probabilistic map for the essential functions by integrating the data from the ‘gold standard’ for mapping brain functions (direct cortical electrostimulation) in a large set of patients. In particular, the authors’ findings challenged two aspects of the classical theories of brain organization. First, their data added new and more direct evidence for the theory that the ventral premotor cortex (PMC), not the classical Broca’s area (Bizzi et al., 2012), is the speech output region. Second, these authors reported that the crucial epicentres for speech output were not lateralized to the dominant hemispheres. A bilateral cortical requirement for speech output was demonstrated in this article. These results have major implications for brain surgery, and this conclusion has the potential to change neurosurgeons’ traditional surgical philosophy.

Tate et al. (2014) observed that the region of interest-based probability of anarthria/arrest (speech output) in the ventral premotor cortex of the left hemisphere is 83%, whereas this probability is only 4% for the pars opercularis. Thus, the authors concluded that the bilateral ventral PMC served as the final common pathway for speech output and that Broca’s area was only involved in the higher-order aspects of language. This result is slightly different from our personal experience; therefore, we applied a similar method to perform a probability analysis for the ventral PMC and pars opercularis using our data from 69 Chinese-speaking patients. The only methodological distinction is that we used a combination of navigation and intraoperative imaging to project the stimulation sites to the standard brain instead of using landmarks only. Our probability calculations suggested a 79% probability of anarthria/arrest with stimulation of the left ventral PMC, which is similar to the results (83%) obtained by Tate et al. (2014). However, the probability of speech arrest with the left pars opercularis is clearly higher in our series (32% compared with 4%) than that in Tate et al. (2014), indicating that the left pars opercularis still has important functions for speech production. In a recent study with a larger sample size (250 patients), Sanai et al. (2008) reported that the largest percentage of total stimulations at the sites in the pars opercularis is 26.7% (the percentage in the ventral PMC is 30.3%), further supporting our hypothesis.

In addition, arcuate fascicle fibre tracking data indicated that the majority of streamlines of the arcuate fasciculus projected into the ventral PMC and that a minority of streamlines reached the pars opercularis (Henning Stieglitz et al., 2012); these observations provided the structural basis for our inference because the arcuate fasciculus and the superior longitudinal fasciculus were suggested to support sensory-motor mapping of sound-to-articulation (Hickok and Poeppel, 2007). To estimate the reliability of the structure basis, we also reconstructed the arcuate fascicle/superior longitudinal fasciculus (Catani et al., 2005) in 18 right-handed healthy subjects and in 34 right-handed patients (from the above-mentioned 69 patients) with intraoperative electrostimulation of the ventral PMC and the pars opercularis. In 14 (78%) of the healthy subjects, the frontal terminal territories of the arcuate...
fasciculus/superior longitudinal fasciculus were localized only in the ventral PMC (Fig. 1A), and in four (22%) of the subjects, the terminal territories of the arcuate fasciculus/superior longitudinal fasciculus were localized in both the ventral PMC and the pars opercularis (Fig. 1B). Furthermore, comparing the terminal territories with the intraoperative electrostimulation in patients revealed that the goodness-of-fit in the pars opercularis was 82% (Fig. 1C and D), and that in the ventral PMC was 86% (Fig. 1E and F). These findings indicate that the method of predicting the speech output regions based upon the frontal terminal territories of the arcuate fasciculus/superior longitudinal fasciculus is reliable.

Although the ventral PMC plays a key role in speech output for most people, in some subjects, the role of pars opercularis in the speech output function should also be considered, not only the high-order functions of language processing described in Tate et al. (2014).

Figure 1 Tractography reconstruction of the arcuate fasciculus (red)/superior longitudinal fasciculus (anterior part: blue; posterior part: green) using the two region of interest approach as described by Catani et al. (2002). (A) The frontal termination territories of the arcuate fasciculus/superior longitudinal fasciculus were only localized in the ventral PMC (yellow ellipse) in 14 healthy subjects. (B) The frontal termination territories of the arcuate fasciculus/superior longitudinal fasciculus were localized in both the ventral PMC and the pars opercularis (yellow ellipse) in four healthy subjects. (C and D) The frontal termination territories of the arcuate fasciculus/superior longitudinal fasciculus localized in both the ventral PMC and the pars opercularis were consistent with the intraoperative stimulation mapping in an illustrative patient with left temporal-insular glioma. (E and F) The frontal termination territories of the arcuate fasciculus/superior longitudinal fasciculus localized in only the ventral PMC were consistent with the intraoperative stimulation mapping in another illustrative patient with left frontal glioma.
The generation of a probabilistic map for speech output in the human cortex is also of significance to guide the chosen language tasks during preoperative functional MRI. Language functional MRI has been used extensively in the last decade for both clinical and research purposes. However, the reliability of language functional MRI has always been widely questioned. Giussani et al. (2010) reviewed studies that compared language functional MRI with direct cortical electrostimulation and reported contradictory results. An important explanation for these findings is that the tasks most commonly used (silent verb generation or picture naming) in preoperative language functional MRI may activate more cortices associated with cognitive functions (such as the left inferior frontal gyrus, the middle frontal gyrus and the superior temporal gyrus) than the basic speech output regions. In our clinical practice, we usually use three language functional MRI tasks for preoperative planning (silent verb generation, silent picture naming and covert recitation of familiar Chinese poems). To select suitable tasks, we performed a group-level functional MRI analysis and separately generated functional MRI-based probability maps of functional activation for three tasks in 15 patients with left hemisphere gliomas (unpublished data). We observed that the patterns of picture naming and verb generation were similar to each other but were completely different from that of covert recitation. Interestingly, by comparing our data with the patterns of picture naming and verb generation, we found that the pattern of covert recitation (functional MRI) resembled that of speech output in both the left and the right hemispheres. Therefore, we deduced that the simplest functional MRI task (covert recitation) might be the best one for determining the preoperative localization of the basic speech output function. Finally, although the authors have presented remarkable work regarding the distribution of functional regions, some inherent limitations should not be ignored. First, the authors included only low-grade glioma, which is a slow-growing tumour that allows the brain many years of functional plasticity, recruiting perilesional or remote areas within the ipsilesional hemisphere and/or contra-hemispheric homologous areas (Duffau, 2006, 2013; Desmurget et al., 2007). Brain plasticity may affect the accuracy of the probabilistic map. Second, the patients in this article were recruited from hospitals in France. Given this information, we assumed that most of these patients spoke alphabetic languages (e.g. French and English), which differ from pictographic languages (e.g. Chinese) in many aspects (Tan et al., 2000; Siok et al., 2004; Chen et al., 2009). Thus, probabilistic maps based on alphabetic languages may not be applicable to all languages. We constructed similar probabilistic maps for Chinese-speaking patients and analysed the differences between a pictographic or character-based language (Chinese) and an alphabetic language (English) (unpublished data). We believe that our work could be an important supplement to this article.

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References