A possible role of BA8 in pre-surgical fMRI

J.Valk, MD, PhD

Korbinian Brodmann

Homage to an exceptional neuroscientist

In 1909, 100 years ago, Brodmann published his cytoarchitectonal map of brain areas. Although the Brodmann areas have been discussed, debated, refined, and renamed exhaustively during a century, they remain the most widely known and frequently cited cytoarchitectural organization of the human cortex (Wikipedia). Functions have been attributed to these areas, such as the sensory cortex, the motor homunculus, the visual cortices and the linguistic areas (Korbinian Brodmann: Vergleichende Lokalisationslehre der Grosshirnrinde in Ihren Prinzipien dargestellt auf Grund des Zellenbaues, Johann Ambrosius Barth Verlag, Leipzig, 1909).

Brodmann area 8 has a diffuse but clearly present internal granular layer(IV); sublayer 3b of the external pyramidal layer(III), has densely distributed medium sized pyramidal cells; the internal pyramidal layer (V) has larger ganglion cells densely distributed with some granule cells interspersed; the external granular layer (II) is denser and broader; cell layers are more distinct; the abundance of cells is somewhat greater.
**Brodmann area 8**, or BA8, is part of the frontal cortex in the human brain. Situated just anterior to the premotor cortex (BA6) it includes the frontal eye fields (so-named because they are believed to play an important role in the control of eye movements). Damage to this area, by stroke, trauma or infection, causes tonic deviation of the eyes towards the side of the injury. This finding occurs during the first few hours of an acute event such as cerebrovascular infarct, or hemorrhage.

The area seems also involved in the management of uncertainty. A functional magnetic resonance imaging study demonstrated that Brodmann area 8 activation occurs when test subjects experience uncertainty, and that with increasing uncertainty there is increasing activation (Volz KG, et al. 2005)

An alternative interpretation is that this activation in the frontal cortex encodes "hope", a higher-order expectation positively correlated with uncertainty and with intellectual ambiguity (Ketteler et al., 2008)

**BA8 in fMRI**

In the last 2 years we have performed >100 presurgical fMRI’s for three neurosurgical centers. We developed robust paradigms to activate eloquent centers of the brain, including motor strip, the visual cortex, areas involved in memory and, perhaps most important, areas governing speech and language

It is evident that in neurosurgery data about the position of eloquent areas, the establishment of dominance in linguistic functions and their relation towards lesions in the brain are crucial in preparing brain surgery. In activation of language areas we noted that the areas of Broca and Wernicke are not always in their expected position, with or without the displacement by mass lesions.

**fMRI results in evoking reactions in language area’s**

To activate the areas of Broca and Wernicke several paradigms are used: word generation by generating words beginning with a letter or a group of letters on the projection screen, by using a variation of the TV show “what’s the question”, by
listening and understanding, and a variation of the Tower of London test. All reactions should be produced by "imagining" without speaking. In all cases a simple "on-off" paradigm was used: activation vs. rest. The first example shows a typical result of a word generation test.

fig. 1 fMRI of patient with left frontal low-grade glioma; activation of expressive speech shows mainly activation on the left side and some on the right. BA8 shows activation on the left confirming bilateral representation of Broca, with dominance on the left. The relation to the tumor is also well demonstrated.

We noticed that in all but 2 patients the word generation paradigm not only activated the Broca area, but also BA8 on the same side as the Broca activation. The transverse and sagittal images showed next in another patient confirm the activation of BA8 and the extension of this area.

Fig. 2

Fig. 2 Transverse images show activation of Broca on the left, with also BA8 activation on that side; the sagittal image shows the medial extension of BA8.
Figure 3 shows that displacement of the Broca area may occur by tumors in the peri Sylvian region, without loss of functionality. Note the newly developed close relation between Broca activation and BA8.

Fig. 3
Displacement upwards of Broca on the left side, and activation of BA8. From these images it is clear that the arcuate fibers are displaced as well, if not distorted.

Since the introduction of Diffusion Tensor Imaging (DTI) and Fiber Tracking (FT) imaging the connectivity" of the brain, the "wiring"of functionally connected brain areas has drawn attention. DTI-FT has been proven capable of showing the arcuate fasciculus, connecting the areas of Broca and Wernicke. A combination of visualized tracts is shown in fig. 4 The wiring is displaced, the functionality clinically not evident disturbed.

Fig.4: tractography:
- fasciculus arcuatis
- corticospinal tract
- corpus callosum
- temporo-occipital fasciculus
These fibers can be traced separately and give a detailed view of the fiber connection and where applicable their distortions or displacement. This is shown in fig. 5

![Broca and Wernicke](image)

fig. 5. A sagittal-oblique and AP view of the fasciculus arcuatus. When this fasciculus can be traced there is a good correspondence with function of the Broca-Wernicke connection. If distorted there is a good clinical correspondence with the well-known different types of aphasia.

It seemed logical to us to see whether such a connection could be found between the Broca area and BA8, No such connection could be traced.

![Fig. 6](image)

Fig. 6. In patients with and without tumor in the language areas fiber tracking, either starting in BA8 or in Broca, was performed. We did not succeed in establishing “wiring” between the 2 areas, Either this is a technical insufficiency or the combined activation of Broca and BA has another background, for example the introduction of “uncertainty” in the execution of the requested task.
**Conclusion:**

Although the connection between Broca and BA8 could not be established in the same way as the Broca-Wernicke connection the synchronicity between the activations makes it useful to confirm the activity of Broca by the activation of BA8, especially in those cases where there is displacement of Broca, where language dominance is important, or in cases with bilateral activation when a quantifiable difference between the two sides exists. This, of course, important in pre-operative cases, but has already great impact on the study of linguistic development and aphasias.

**References:**

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J.Valk, MD, PhD
Professor of Radiology and Neuroradiology
VU academic medical center, Amsterdam
Studies performed at the MRI center
Amsterdam

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