

大脳島皮質前部の発声関連領域 —運動理論と関連して—

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あらまし 島前部は失語症を起こす部位のひとつである。島の最前部腹側に側頭極と類似の組織学的構造をもつ領域があり (PrpS)、視覚、嗅覚以外の感覚が皮質間結合によって集約される高次の連合野であると考えられる。この領域は喉頭、構音に関する補足運動野ではないかと考えられている領域 (後腹側前頭弁蓋、ProM) と双方向性に結合があり、島性の失語症が感覚性、運動性両方を含むことの基盤になっている。サル脳においては ProS, ProM の間は感覚系と運動系が直接結合をもつ部位であり、またこの1つの部位は Broca 言語野と考えられている領域とも結合をもっている。音声知覚の運動理論については、知覚系が運動系にあるテンプレート参照説と考える説もあり、また単に知覚においては運動系が巻き込まれていると考える説もある。この島前部皮質付近の領域は運動理論に必要な神経ネットワークが存在する部位であると考えられる。

キーワード 島皮質、ProS、ProM、運動野、運動理論、音声知覚、AChE

Anterior Ventral Insula as a Brain for Vocalization — A neural network for motor theory of speech perception —

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Abstract Anterior Insula is one of the areas for aphasia. Ventral part of anterior Insula (ProS) has a similar histological structure with temporal pole, and the area for sensory integration by cortico-cortical projection, except visual and olfactory modality. This area has bilateral connection with caudo-ventral part of frontal operculum (ProM), which are supposed to be a supplementary motor cortex for laryngeal and mouth movement. This connection between ProS and ProM may explain reason for mixed type aphasia by Insular infarction. In macaque brain, ProS and ProM has direct connection between them, and both of them has connection with the cortical area, which are analogue for human Broca area. These cortical connection may be the basis for neuronal network to explain motor theory of speech perception, in which, sensory system uses template in motor system while speech perception, or speech perception involves motor system. ProS may be also related with emotion, which is a drive for vocalization, and plasticity, which is one of basic character of language development

Keywords Insula, ProS, ProM, Motor cortex, Motor theory Speech perception, AChE

1. Introduction

Recent reports indicated that infarction in Insula would lead to symptom of aphasia (Dronkers, 1996; Tanji, et al, , 2001; Cereda, et al, 2002; Saygin, et al, 2004). These reports also suggested especially anterior part of Insula has a important part in language disturbance. Interestingly, insular type aphasia contains not only sensory, but also mixed type aphasia

(Dronkers, 1996; Cereda, 2002).

Insula received various modalities of sensory information, except vision and olfaction (Table 1). Taste, pain, vestibular, visceral, vibratory, and deep sensation are projected directly from thalamus to Insula, and simultaneously these sensation runs through Insula by cortical connection. Auditory and Somatosensory sensation mainly enters insula as

Sensory Functions in Insula

- Taste (Gustatory)
- Pain
- Vestibular
- Visceral
- Vibratory
- Somatosensory
- Deep sensation
- Auditory

Table 1

a higher order cortex. So Insula is a cortical area, which receives input from thalamus, and also an area for higher order sensory integration. Especially, the most anterior and ventral part of Insula ProS has an undifferentiated structure as temporal pole (Kosaki, 2006-a; Pandya 1973)

This area of ProS has bilateral connection with motor area of ProM (Kosaki, 2006-b; Chippolini and Pandya, 1999) ProM is considered as a supplementary motor area for laryngeal and mouth movement (Chippolini and Pandya, 1999). So anterior Insula is the area where sensory and motor meet.

For a long period, researcher have sought evidence for motor theory of speech perception (Libermann and Mattingly, 1985). Relationship of ProS and ProM is a good candidate, in which neural networks for motor theory may be investigated.

In this article, histological features of area ProS is investigated and upon that, the possible neural basis for motor theory of speech perception is to be discussed.

2. Materials and Methods

Brain of twelve rhesus macaques were used for this study. (Jones, et al., 1995). Alternate sections were mounted and stained with thionin or stained, free-floating, CytochromeOxidase (CO), Achetylcholine Esterase (AcheE), Calbindin (CB), Parvalbumin (PV), Calretinin (CR) and SMI 32 staining were

also applied. Staining in immunohistochemistry were done by the methods described in the article by Kosaki, et al 1997 (Kosaki, et al, 1997; Jones, et al, 1995; Molinari, et al. 1995). Staining for CO was done following the methods in article by Wong-Riley (Ron-Riley, 1979) and for AcheE was done by modified Karnovsky-Roots Method (Karnovsky MJ, Roots L, 1964; Mesulam and Mufson, 1982).

3. Results

In many anatomical reports, Insula has been separated in to three parts; agranular (anterior), dysgranular (middle), and granular (posterior) by thionin (Nissle) staining (Pandya, and Sanides, 1973; Mesulam and Muffson, 1982). However Pandya and colleagues paid attention to ventral part of anterior Insula and proposed it would be an independent area (Pandya, and Sanides, 1973; Chippolini and Pandya, 1999).

Immunostainings showed that ventral part of anterior Insula has a different feature than dorsal part of that. Ventral part of anterior Insula (ProS) showed few laminar structure in these staining and looked undifferentiated (Fig. 1). This features of ProS has much similarity with that of temporal pole.

Among three calcium binding protein stains, PV staining showed weak color in ProS, and CB and CR showed thick.



Fig. 1 Ache Anterior part of Insula
Arrow indicate area ProS.



Fig. 2 AChE stained section of ProS

Fig.2 showed an AChE (Acetylcholine esterase) stained section of ProS level. It showed a laminar distribution pattern. Cholinergic fibers mainly observed layer II-III, deep layer IV, and layer V-VI. This thick distribution of cholinergic fibers suggested a possible role of ProS in emotion and plasticity.

4. Discussion

ProS spread at anterior ventral Insula and on inferior circular sulcus.

ProS is weakly stained with PV and thickly stained with CB and CR. This may suggest that in Pros processing is mainly of long time frame. However, Insula, which is the source of input to ProS, contains both PV-rich and CB/CR-rich areas, and may be doing both processing of short time frame (high temporal resolution) and of long time fraom (high spatial resolution). Inferior circular sulcus is he area, where auditory spatial thalamic input reaches (Burton and Jones, 1976). So it may be natural to suppose ProS deals with information of temporal and spatial.

Thick distribution of cholinergic fibers in

this area may suggest the possible role in emotion, which is a drive for vocalization and plasticity, which is necessary for language development and learning.

ProS has bilateral connection with area M and Broca area in monkey (Kosaki, 2006-B, Chippolini anc Pandya, 1999). The former connection, which is sensory and motor areas directly connect with each other, has much similarity with relationship between somatosensory and motor areas. So it would be natural that ProS- ProM connection receives influence of cerebellum and basal ganglia (Pandya and Barbas, 1985) and has much capability in plasticity.

ProS and ProM both has bidirectional connections with areas 44/45, which are supposed to be the macaque analogue of human Broca area (Preuss and Goldman-Rakic, 1982, Chippolini anc Pandya, 1999). This connection would be translated as "Sensory-Prefrontal-Motor" relationship. This connection may be convenient for explanation for activity of Broca area in passive listening in imaging studies. It looks as logical result to investigate an template of speech sounds in prefrontal areas than pure motor areas.

Insula itself is also regarded as an area of emotion. ProS, too, has much relationship with visceral sensation, must have much to do with emotional function. Emotion is known as a drive for vocalization and emotional cortical areas, such as periaqueductal gray matter in mid brain or anterior cingulated cortex is a area to initiate vocalization. Further question exist in role of ProS, as an emotional brain, in vocalization, speech, and language.

5. Conclusion

Ventral part of anterior Insula (ProS) has a similar histological structure and thick distribution of cholinergic fibers as in temporal pole. And ProS is the area for sensory integration by coritco-cortical projection, except visual and olfactory modality. And has bilateral connection with caudo-ventral part of frontal operculum (ProM), which are supposed to be a supplementary motor cortex for laryngeal and

mouth movement. This connection between ProS and ProM may explain reason for mixed type aphasia by Insular infarction. In macaque brain, ProS and ProM has direct connection between them, and both of them has connection with the cortical area, which are analogue for human Broca area. These cortical connection may be the basis for neuronal network to explain motor theory of speech perception. ProS may be also related with emotion, which is a drive for vocalization, and plasticity, which is one of basic character of language development

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