LARYNGEAL MOTORCORTEX AND ITS EFFERENT SUBCORTICAL PROJECTIONS

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The descending pathway of the laryngeal motorcortex has been evaluated in the rhesus monkey using the anterograde tracing technique.
The cortical larynx area plays a crucial role in voluntary control of vocal fold movements. Its bilateral destruction in human patients results in a complete loss of speech and song. Electrical stimulation of this area produces isolated vocal fold movements in man, chimpanzee, rhesus monkey and squirrel monkey. Despite its importance in vocal control, little is known about its neuroanatomical connections.

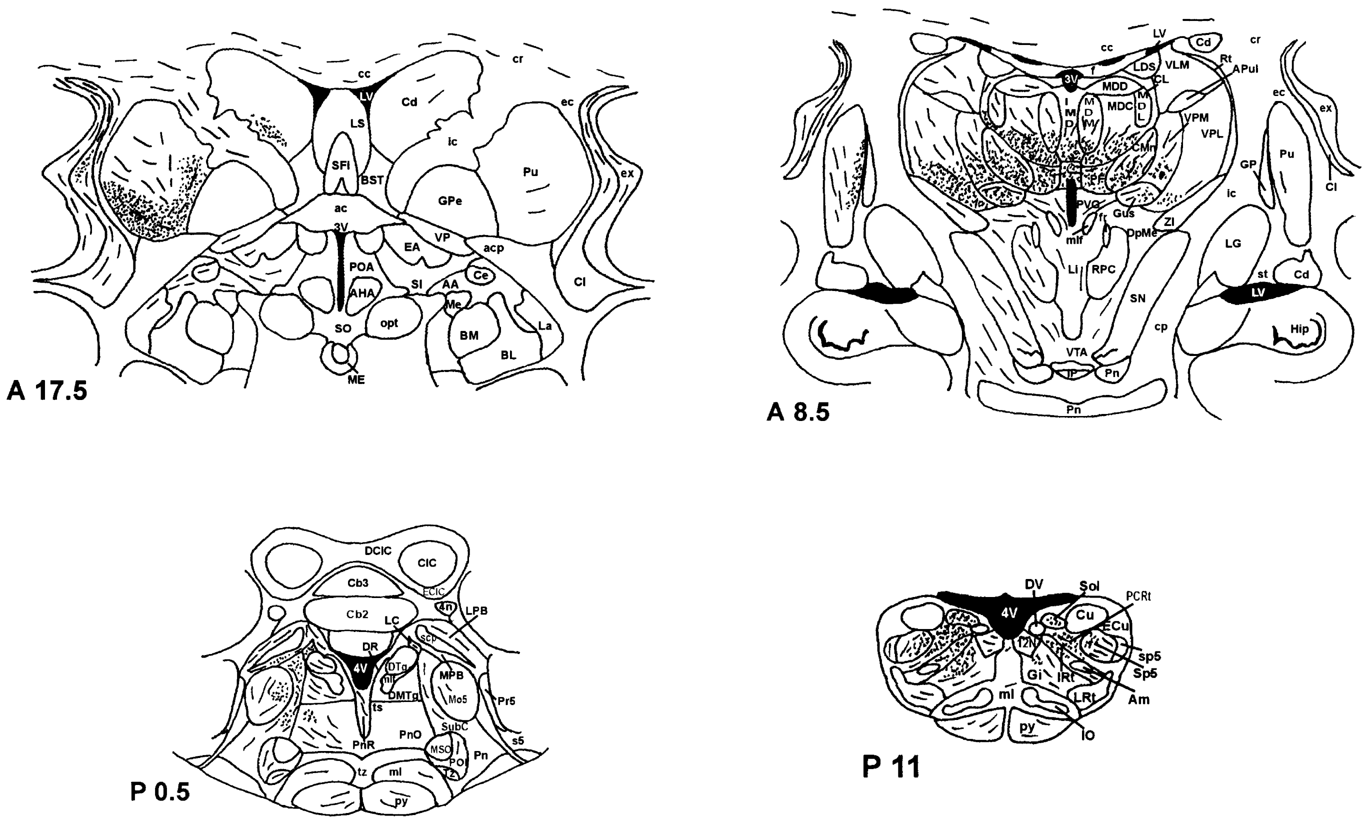
The experiments were carried out in three rhesus monkeys. Under general anaesthesia, the animals' motorcortex between the inferior ramus of the arcuate sulcus and subcentral dimple was explored for sites yielding vocal fold movement observed by indirect laryngoscopy while stimulated. When a site of vocal fold adduction was found, it was injected with an anterograde tracer, biotin dextranamine. After a survival period of 7 weeks, the animals received an overdose of narcoren and were perfused with physiological saline and paraformaldehyde solutions; the brains were processed immunohistologically. Microscopic evaluation was done in the bright and dark field.

The efferent subcortical projections of the laryngeal motorcortex largely correspond to the general scheme of mammalian motorcortical projections.
Within the telencephalon, terminals were found in the ventral putamen over a large anteroposterior distance. Terminals in the caudate nucleus were seen mainly along the internal capsule. In the claustrum, terminal labelling was not only found in the rostrodorsal part, but also at two separate positions in the ventral part. The ventral putamen receives the strongest projection of all telencephalic subcortical structures and, therefore, represents the main basal ganglia output structure of the laryngeal motor cortex.
The thalamic projections are similar to those reported for the squirrel monkey's laryngeal motor cortex and to the projections of the Java monkey's face motor cortex, except of projections to the nucleus ventralis anterior and pulvinar complex found only in the present study.
One of the most heavily labelled thalamic nuclei is the nucleus ventralis lateralis. It is part of two motor control loops: the cortico-ponto-cerebello-thalamo-cortical and cortico-striato-pallido-thalamo-cortical pathways. Lesions in the ventrolateral nucleus of man have been reported to cause monotonous and breathy voice. Its electrical stimulation produces vocalization.
Within midbrain, the periaqueductal grey (PAG) represents a crucial relay station of the limbic vocalization pathway. The PAG destruction is known to block vocalization elicited from limbic structures. In contrast, there is no effect at all of PAG lesions on vocal fold movements elicited from the cortical larynx area. This lack fits well with the finding of the present study that there is no direct connection of the cortical larynx area with the PAG.
In the lower brainstem, no terminals were found in the nucleus ambiguus, that is, the site of the laryngeal motoneurones. A lack of cortico-ambigual projections was also reported for the squirrel monkey, tree shrew, cat and rat. In humans, in contrast, direct connections of the motor cortex with the nucleus ambiguus do exist. The direct cortico-ambigual connection seems to be a recent evolutionary acquisition and one of the possible prerequisites for speech development.
On the other hand, the pontine and medullary reticular formation as well as the solitary tract nucleus are found to receive direct input from the cortical larynx area. These structures are known to project to the nucleus ambiguus, and therefore, could be candidates for cortico-ambigual relay stations.

Literature

1. H.M. Brandt, A.V. Apkarian, Biotin-dextran. A sensitive anterograde tracer for neuroanatomic studies in rat and monkey, J. Neurosci. Meth. 45 (1992) 35-40.
2. M.H. Hast, J.M. Fischer, A.B. Wetzel, V.E. Thompson, Cortical motor representation of the laryngeal muscles in Macaca mulatta,, Brain Res. 73 (1974) 229-240.
3. U. Jürgens, On the elicitability of vocalization from the cortical larynx area, Brain Res. 81 (1974) 564-566.
4. G. Paxinos, X.-F. Huang, A.W. Toga, The rhesus monkey brain in stereotaxic coordinates, Academic Press, New York, 2000.

Fig. 1. Descending pathway of the cortical larynx area.



Abbreviations

Cl Claustrum
CL Centrolateral thalamic nucleus
CMn Centromedian thalamic nucleus
Gi Gigantocellular reticular nucleus
IMD Intermediodorsal thalamic nucleus
IRt Intermediate reticular nucleus
LC Locus coeruleus
MDC Mediodorsal thalamic nucleus, caudal part
MDL Mediodorsal thalamic nucleus, lateral part
MDM Mediodorsal thalamic nucleus, medial part
MPB Medial parabrachial nucleus
PCRt Parvicellular reticular nucleus
PF Parafascicular thalamic nucleus
PnO Pontine reticular nucleus, oral part
Pu Putamen
Rt Reticular thalamic nucleus
Sol Solitary tract nucleus
Sp5 Spinal trigeminal nucleus
SubC Subcoeruleus nucleus
VLM Ventral lateral thalamic nucleus, medial part
VPL Ventral posterolateral thalamic nucelus
VPM Ventral posteromedial thalamic nucleus
Gus (VPMpc) Ventral posteromedial thalamic nucleus, parvocellular part