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Research Report

Direct projections from the central amygdaloid nucleus to the mesencephalic trigeminal nucleus in rats

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ABSTRACT

The amygdala is activated by fear and plays an important role in the emotional response to life-threatening situations. When rats feel threatened, they respond by biting fiercely. Bite strength is regulated by the trigeminal motor nucleus and the mesencephalic trigeminal nucleus (Me5). The Me5 relays proprioceptive signals from the masticatory muscles and the periodontal ligaments to the trigeminal motor and premotor nuclei. The amygdala projects to the trigeminal motor nucleus and the premotor reticular formation. However, it is unknown whether the amygdala projects directly to the Me5. In the present study, neurons of the central amygdaloid nucleus (ACe) were labeled following injection of a retrograde tracer, Fast Blue, into the caudal Me5, and fibers and terminal buttons from the ACe to the Me5 were examined after injections of an anterograde neuronal tracer, biotinylated dextran amine into the ACe. Furthermore, wheat germ agglutinin-conjugated to horseradish peroxidase was injected into the ACe, and labeled fibers and terminal buttons in the Me5 were examined by electron microscopy. Labeled terminal buttons on Me5 somata were more abundant in the caudal than the rostral Me5. Electron microscopic observation revealed that a part of these terminal buttons formed axo-somatic synapses. These results indicate that the ACe sends direct projections to the Me5, and suggest that the amygdala regulates bite strength by modifying neuronal activity in the Me5.

1. Introduction

The amygdala plays an important role in emotional perception and expression (Adolphs and Tranel, 2000; LeDoux, 1996) and in fear response (Davis, 1992; Hilton and Zbrozyna, 1963; LeDoux, 1992, 1996, 2000a, 2000b). In the rat, the lateral amygdaloid nucleus receives projections from sensory cortices and basal forebrain structures and projects to the basolateral, basomedial, and central amygdaloid (ACe) nuclei (McDonald, 1998; Pitkanen et al., 1997). In addition to the lateral amygdaloid projection, the ACe receives projections from the basolateral and basomedial nuclei. The ACe, in turn,

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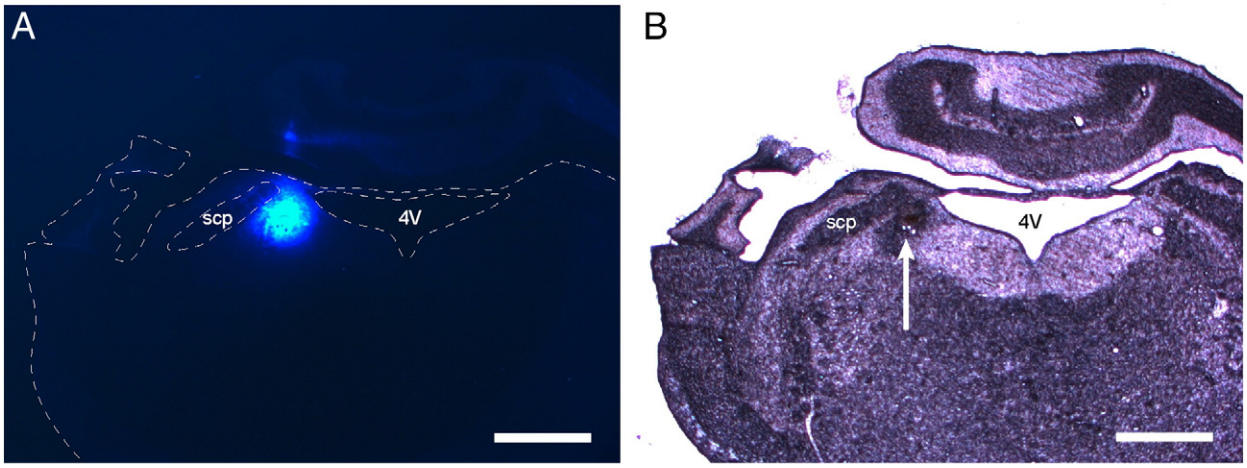

Fig. 1 – Injection site of Fast Blue into the caudal mesencephalic trigeminal nucleus (Me5). (A) A fluorescent photomicrograph. (B) A bright-field photomicrograph of the same field as (A). The arrow indicates the injection site. 4V, fourth ventricle; scp, superior cerebellar peduncle; scale bars, 1 mm.

projects to the hypothalamus and brainstem structures including the periaqueductal gray matter, the ventral tegmental area, the cuneiform nucleus, the parabrachial nucleus, the locus coeruleus, the dorsal raphe, the trigeminal motor nucleus, and the trigeminal premotor reticular formation (LeDoux, 2000a; Mascalo et al., 2009; Van Daele et al., 2011). Within the amygdaloid complex, the ACe plays a critical role in integrating sensory and emotional information as well as in emotional processing.

Previous research has suggested that the initiation and strength of the biting response are controlled by the trigeminal motor nucleus and the premotor reticular formation (Kolta et al., 2000). The trigeminal motor nucleus is thought to be indirectly regulated by the ACe through its projections to the hypothalamus and the pontine reticular formation (Li et al., 1995; Mascalo et al., 2009; Takeuchi et al., 1988). In addition to regulation by the ACe, the trigeminal motor nucleus and the premotor reticular formation are also modulated by the mesencephalic trigeminal nucleus (Me5), which provides proprioceptive signals from the muscle spindles of the masticatory muscles and from the periodontal receptors (Alvarado-Mallart et al., 1975; Hopkins and Holstege, 1978; Jacquin et al., 1983; Krettek and Price, 1978; Shigenaga et al., 1988; Yasui et al., 2004). The Me5 neurons receive projections from the raphe nuclei (Copray et al., 1991; Lazarov and Chouchkov, 1995; Li et al., 2000) and the principal and spinal trigeminal sensory nuclei in the rat (Buisseret-Delmas et al., 1997). In addition, immunohistochemical analyses of various

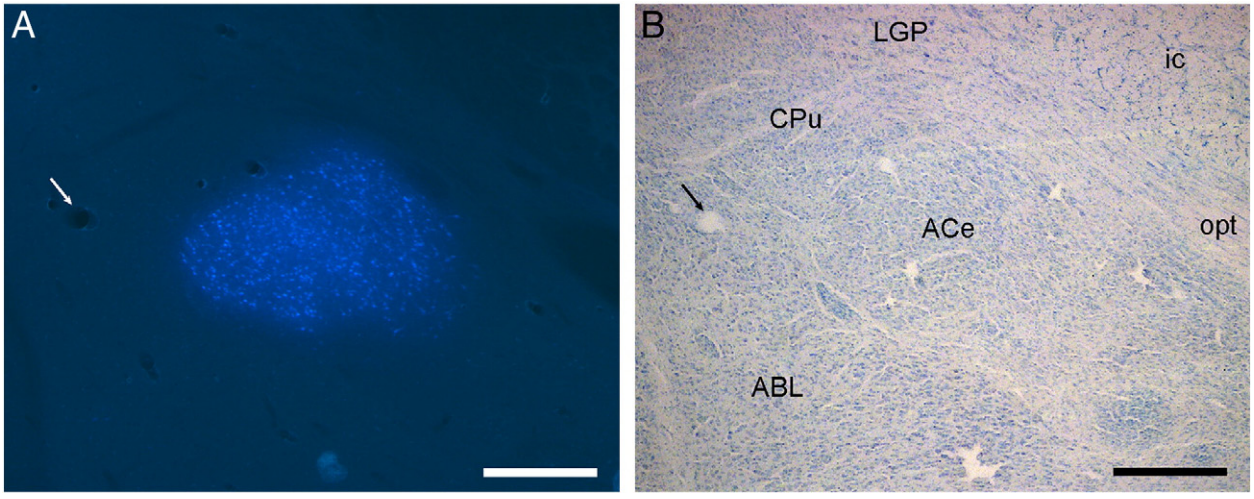

Fig. 2 – (A) A fluorescent photomicrograph showing retrogradely labeled cells in the central amygdaloid nucleus (ACe). (B) A bright-field photomicrograph showing Nissl staining of a similar field as shown in (A) taken from an adjacent section. Arrows indicate the same blood vessel. ABL, basolateral amygdaloid nucleus; CPu, caudate putamen; ic, internal capsule; LGP, lateral globus pallidus; opt, optic tract; scale bars, 500 μm.