available at www.sciencedirect.com

ScienceDirect

www.elsevier.com/locate/brainres

BRAIN RESEARCH

Research Report

Glutamate receptor subunit expression in the rhesus macaque locus coeruleus

Nigel C. Noriega[a], Vasilios T. Garyfallou[a], Steven G. Kohama[a], Henryk F. Urbanski[a,b,c,*]

[a]Division of Neuroscience, Oregon National Primate Research Center, 505 NW 185th Avenue, Beaverton, OR 97006, USA
[b]Department of Behavioral Neuroscience, Oregon Health and Science University, 3181 SW Sam Jackson Park Road, Portland, OR 97239, USA
[c]Department of Physiology and Pharmacology, Oregon Health and Science University, 3181 SW Sam Jackson Park Road, Portland, OR 97239, USA

ARTICLE INFO

Article history:
Accepted 2 August 2007
Available online 9 August 2007

Keywords:
Locus coeruleus
Microarray
Gene array
Rhesus macaque
Glutamate receptor
In situ hybridization

ABSTRACT

The locus coeruleus (LC) is a major noradrenergic brain nucleus that regulates states of arousal, optimizes task-oriented decision making, and may also play an important role in modulating the activity of the reproductive neuroendocrine axis. Rodent studies have shown that the LC is responsive to glutamate receptor agonists, and that it expresses various glutamate receptor subunits. However, glutamate receptor subunit expression has not been extensively examined in the primate LC. We previously demonstrated expression of the NR1 NMDA glutamate receptor subunit in the rhesus macaque LC and now extend this work by also examining the expression of non-NMDA (AMPA and kainate) ionotropic glutamate receptor subunits. Using *in situ* hybridization histochemistry and immunohistochemistry, we confirmed the presence of the obligatory NR1 subunit in the LC. In addition, we demonstrated expression of the AMPA glutamate receptor subunits GluR1, GluR2, and GluR3. More extensive receptor profiling, using rhesus monkey gene microarrays (Affymetrix GeneChip®), further corroborated the histological findings and showed expression of mRNA encoding ionotropic glutamate receptor subunits NR2A, NR2D, GluR4, and GluR6, as well as the metabotropic glutamate receptor subunits mGluR1, mGluR3, mGluR4, mGluR5, and mGluR7. These data provide a foundation for future examination of how changes in glutamate receptor composition contribute to the control of primate physiology.

1. Introduction

The locus coeruleus (LC) is the principal noradrenergic nucleus of the brain and is connected to areas as wide ranging as the cerebral cortex, thalamus, hypothalamus, olfactory bulb, cerebellum, midbrain, and spinal cord (Moore and Bloom, 1979; Foote et al., 1983; Loughlin et al., 1986; Luppi et al., 1995; Berridge and Waterhouse, 2003). Early research implicated LC

* *Corresponding author*. Division of Neuroscience, Oregon National Primate Research Center, 505 NW 185th Avenue, Beaverton, OR 97006, USA. Fax: +1 503 690 5384.
E-mail address: urbanski@ohsu.edu (H.F. Urbanski).

Abbreviations: ACTB, β-actin; AMC, Affymetrix Microarray Core; AMPA, α-amino-3-hydroxy-5-methyl-4-isoxazolepropionic acid; DAB, 3,3′-diaminobenzidine tetrahydrochloride; DMSO, dimethyl sulfoxide; E, estrogen; EAA, excitatory amino acid; GABA, γ-amino butyric acid; GAD, glutamic acid decarboxylase; GAPDH, glyceraldehyde-3-phosphate dehydrogenase; GCOS, GeneChip® Operating Software; GFAP, glial fibrillary acidic protein; GnRH, gonadotropin releasing hormone; LC, locus coeruleus; NE, norepinephrine; NET, norepinephrine transporter; NMDA, *N*-methyl-D-aspartate; OHSU, Oregon Health and Science University; ONPRC, Oregon National Primate Research Center; TH, tyrosine hydroxylase; TDP, Tissue Distribution Program; VGLUT, vesicular glutamate transporter

0006-8993/$ – see front matter © 2007 Elsevier B.V. All rights reserved.
doi:10.1016/j.brainres.2007.08.007

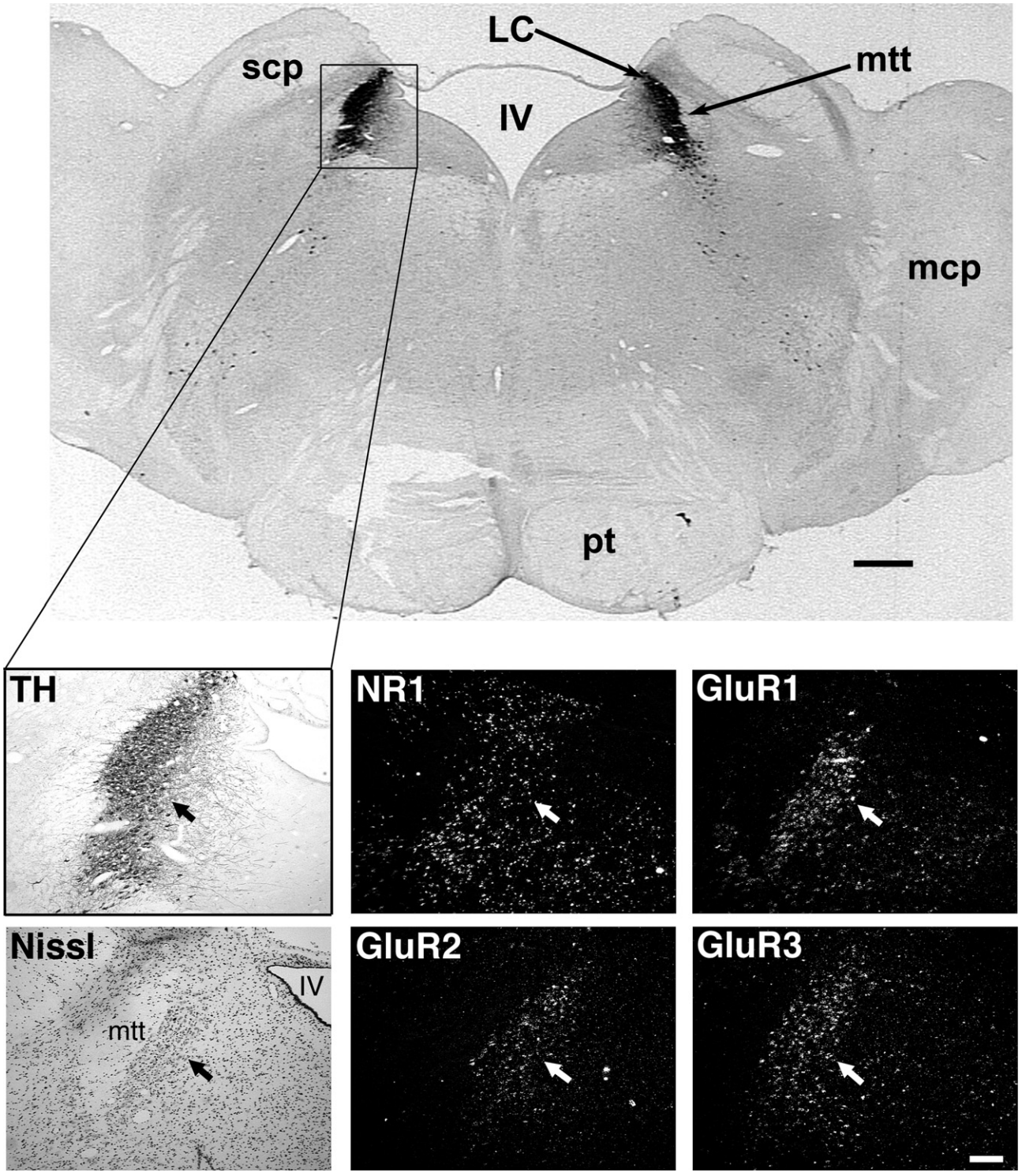

Fig. 1 – Localization of glutamate receptor subunit gene expression in the rhesus macaque LC, as revealed by *in situ* hybridization. The top panel shows a frontal section of the hindbrain immunostained for TH: LC = locus coeruleus; scp = superior cerebellar peduncle; mtt = mesencephalic trigeminal nerve tract; IV = fourth ventricle; mcp = medial cerebellar peduncle; pt = pyramidal tract. Black scale bar = 1 mm. The lower six panels represent adjacent coronal 25-μm sections. The light panels show landmarks used to localize the LC. TH = immunostaining for TH using DAB as the chromogen. Nissl = cresyl violet stain for Nissl substance. The TH-positive neurons of the LC (arrows) lie between the fourth ventricle (IV) and the mesencephalic trigeminal nerve tract (mtt); Dark panels show *in situ* hybridization for glutamate receptor subunits NMDAR1 (NR1), GluR1, GluR2 and GluR3 in the LC. White scale bar = 250 μm.