COCHLEAR INFLUENCES ON DEVELOPMENT OF THE BRAINSTEM AUDITORY SYSTEM

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1. STUDYING THE EAR'S INFLUENCE ON THE DEVELOPING BRAIN

1.1. Introduction

Experimental work from several laboratories, including that reviewed by Hyson and Sanes in this volume, has shown that from the time cochlear nerve synapses are first formed on CNS auditory neurons, the developing ear exerts a powerful influence on the developing brain (see also Moore, 1992). My laboratory has studied how influences from the ear affect survival, form, connectivity, calcium homeostasis mechanisms, and neurotransmitter receptor properties of chick brainstem auditory neurons.

1.2. Manipulating the Developing Chick Auditory System

Because of the many similarities between the auditory systems of birds and mammals and the many advantages of using avian embryos in developmental studies (Rubel and Parks, 1988), we have used a chick embryo model to study the normal development of brainstem auditory circuits and the effects of early hearing loss on this development (Fig. 1). Hearing loss has been produced by surgical destruction of the otocyst or cochlea or by the use of earplugs (Parks, 1997). The otocyst is the embryonic precursor of the inner ear and acousticovestibular nerve; since cochlear nerve axons do not enter the brain until embryonic day (E) 4 and the cochlea is not functional until about E11 (Rubel and Parks, 1988), surgical removal of the otocyst (unilaterally or bilaterally) on E3 results in the auditory CNS developing without ever receiving synaptic input from the ear (Parks, 1979; see Fig. 2). In some experiments, the cochlea has been surgically destroyed in chickens after hatching. Earplugs formed by injecting liquid plastic hearing aid sealer into the external auditory meatus of E18 chick embryos have also been used to produce a severe (40–50 dB) conductive hearing loss combined with some sensorineural...
Figure 1. Schematic representation of chick brain stem auditory anatomy. Cochlear division of the eighth cranial nerve (VIII) provides tonotopic innervation of nucleus angularis (NA) and nucleus magnocellularis (NM), forming large calyx-like axonal endings in NM. Each NM neuron sends one axon branch to dorsal dendrites of neurons in ipsilateral nucleus laminaris (NL), and another branch to ventral dendrites of contralateral NL. Axon terminal fields of NM neurons are oriented perpendicularly to the axis of tonotopic organization, which extends from posterolateral (representing low-frequency sounds) to anteromedial (high frequencies). This axis also defines gradients in NL dendritic length and number; cells have shorter but more numerous primary dendrites anteromedially than caudolaterally. IV, fourth ventricle.

Figure 2. Photomicrograph of protargol-stained coronal section through the skull and brain stem of E9 chick embryo from which the right otocyst had been removed surgically at E3. The eighth nerve appears normal on unoperated left side (arrow), but is absent on the right (*). Brain stem auditory nuclei (NA, NL, and NM) are present bilaterally.