Spinal Branching of Rubrospinal Axons in the Cat

Y. Shinoda¹, C. Ghez and A. Arnold²
Rockefeller University, New York, N.Y. 10021, USA

Summary. The branching patterns of rubrospinal (RS) axons projecting to the cervical spinal cord between C3 and C8 were studied in the cat. RS neurons were identified by their antidromic responses to microstimulation of local axon branches within the cervical gray matter. Twenty-six of 58 RS neurons projecting to the cervical gray matter also sent axon branches to the thoracic spinal cord. Two out of 40 of these RS neurons also sent axon branches to the lumbar spinal cord. Using a collision technique, it was demonstrated that stem axons of rubrospinal neurons commonly sent multiple collaterals to different cervical segments.

Neurons projecting to the cervical spinal cord alone were located in the dorsal quadrants of the red nucleus. Those projecting to cervical, as well as to more caudal segments, were intermingled with the former, and in slightly more ventral portions of the red nucleus. The presence of RS neurons projecting to widely separate levels of the spinal cord suggests that individual RS neurons may be capable of ultimately influencing two or more different motoneuron pools.

Key words: Rubrospinal neurons - Axon branching - Spinal cord - Microstimulation

Introduction

Corticospinal (CS) neurons and rubrospinal (RS) neurons have many common features. Both populations have excitatory monosynaptic connections with interneurons in the intermediate zone of the spinal cord (Lundberg et al., 1972; Shapovalov, 1966; Hongo et al., 1969a; Bayev and Kostyuk, 1973; Illert et al., 1975a; Illert et al., 1975b). In the cat, influences from both CS and RS neurons are transmitted to motoneurons through such interneurons, some of which receive convergent input. Microstimulation within the motor cortex and the red nucleus evokes contraction of single muscles (Asanuma and Ward, 1971; Ghez,

¹ Dr. Y. Shinoda’s present address: Department of Neurophysiology, Brain Research Institute, University of Tokyo, Bunkyo-ku, Tokyo, Japan
² Dr. A. Arnold’s present address: Department of Psychology, UCLA, Los Angeles, California, USA
1975) and the two systems are somatotopically organized. Lesions of either system produces impairments in the control of distal extremity musculature (Kuypers, 1964).

Both CS and RS neurons send axon collaterals to brain stem nuclei (Endo et al., 1973; Anderson, 1971). In addition, it has recently been shown that, in spite of the somatotopic organization of the motor cortex (Asanuma, 1973; Brodal, 1969), many CS neurons terminate in widely separate segments of the spinal cord (Shinoda et al., 1976). Such observations suggest that a subpopulation of cells can influence the activity of several muscles. The present experiments were undertaken to determine if the same principle holds true for the rubrospinal system.

It will be shown that many rubrospinal neurons send axonal branches into the cervical gray matter before terminating at more caudal levels of the spinal cord.

Methods

Twenty adult cats (2.5–3.4 kg) were anesthetized with sodium pentobarbital (Nembutal, 35 mg/kg) and additional doses (10 mg/kg) given when necessary. The spinal cord from C3 to Th3 and from Th12 to L2 was exposed, covered with mineral oil and kept at 36–38°C by radiant heat. The right occipital cortex was exposed and a portion of the cortex was aspirated to allow electrode penetrations in the right red nucleus. The exposed cortex was covered with warm mineral oil. Body temperature was maintained at 36–38°C with a heating pad.

Details concerning the stimulating electrodes and their arrangement, as well as the recording electrodes, have been given elsewhere (Shinoda et al., 1976). Briefly, 12 glass-insulated tungsten microelectrodes were inserted one by one into the cervical gray matter between C4 and C8 as shown in Figure 4A, about 2 mm to the left of the midline and 2.5 mm deep. The electrodes were fixed to a single longitudinal plate which could be moved vertically by a microdrive. Additional electrodes were used to stimulate rubrospinal tract fibers within the lateral funiculus at C3, Th3 and L1. In half of the experiments, these consisted of pairs of silver ball electrodes placed on the surface of the lateral columns, in the other half, single varnished tungsten electrodes (0.5 mm exposed tip) were inserted about 1.5 mm into the lateral funiculus. Cathodal pulses of 0.3 msec were applied through the implanted electrodes relative to a reference electrode in the lower back. Bipolar stimulus pulses of the same duration were used in the case of the pairs of ball electrodes.

Single neurons in the red nucleus were recorded extracellularly with glass insulated tungsten microelectrodes. The region explored went from the stereotaxic planes A 2.5 to 5.5 and L 1.0 to 3.5. In each experiment electrolytic lesions were made in the spinal cord and the stimulating sites were reconstructed from the histological sections. Electrolytic lesions were also made in the red nucleus and the recording sites reconstructed in eight experiments.

Results

Criteria for Antidromic Activation of Rubrospinal Neurons

The recording electrode was positioned in the red nucleus on the basis of the antidromic field potentials evoked by stimulation of the contralateral rubrospinal tract at C3. Characteristic positive-negative antidromic field potentials were recorded when the electrode tip was in the nucleus (Tsukahara et al., 1968; Hongo et al., 1969a). With the recording electrode in the red