Effect of Differential Blocking of Motor Axons on Antidromic Activation of Renshaw Cells in the Cat

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Summary. Attempts were made to study differences in the relative effectiveness of different size ranges of motor axons to Renshaw cells by differential blocking of larger fibers of the gastrocnemius nerve in cats anesthetized with Nembutal.

1. Differential blocking of larger fibers in the nerve was successfully obtained by applying trapezoid wave current to the nerve.

2. It was shown that more than half (58.1%) of the Renshaw cells receive homogeneous inputs from α motor axon collaterals, 25.8% of the cell receive collateral inputs from a certain group of fibers, and 12.5% of the Renshaw cells were activated by “γ range” fibers.

Key words: Cat — Renshaw cell — Antidromic activation — Differential blocking

Introduction

It is generally known that Renshaw cells receive inputs monosynaptically from axon-collaterals of α-motor fibers (Renshaw, 1946; Eccles, Fatt and Koketsu, 1954), polysynaptically via dorsal roots (Renshaw, 1946; Frank and Fuortes, 1956; Curtis, Phillis and Watkins, 1961; Wilson, Talbot and Kato, 1964; Curtis and Ryall, 1966) and polysynaptically from higher nervous structures (Haase and van der Meulen, 1961; MacLean and Leffman, 1967; Haase and Vogel, 1971). Among them the input through motor axon collaterals is apparently the main excitatory input to Renshaw cells (Wilson, 1966).

If activation of Renshaw cells via motor axon-collaterals is of functional importance in controlling muscle contraction, then it may be worthwhile to investigate quantitatively inputs from axon-collaterals stemming from motor fibers with various diameters. Renshaw (1946) and later Longo, Martin and Unna (1960), Eccles et al. (1961) and Willis (1971) investigated the effect of varying the intensity of antidromic stimulation upon Renshaw cell discharge. More systematically Ryall et al. (1972) reported on the contribution of various motor fibers upon Renshaw cell activation by antidromically stimulating motor fibers with increasing stimulus strength, and by orthodromically stimulating motor axons with reflexly evoked volleys. By the latter method contributions from smaller diameter α motor fibers could be estimated if Henneman’s (1968) “size principle” holds, although the effects from γ motor axons would not have been tested. By the former method temporal and/or spatial summation of subliminal EPSPs elicited by thicker fibers might have distorted the experimental results.
In order to investigate the contribution from motor fibers with various diameters, it is desirable to block thicker fibers selectively and activate only the fibers having a particular range of conduction velocity. In the present experiments, such differential blocking was successfully applied to motor fibers and the effects from these different motor fibers upon Renshaw cell discharge were studied.

A part of the experimental results was reported at the 50th Annual Meeting of Physiological Society of Japan (Kato and Fukushima, 1973).

Methods

Experiments were performed on 16 cats (1.7—3.3 kg body weight) anesthetized with intraperitoneal injection of 20 mg/kg of Nembutal which was supplemented during the experiment as necessary. After the animal was fixed in a metal frame laminectomy was performed in the usual manner exposing the spinal cord from L4 caudally. Ipsilateral dorsal roots L6—S2 were cut. The gastrocnemius nerve was dissected and cut at the popliteal fossa. The exposed spinal cord and popliteal fossa were covered with warmed mineral oil, the temperature of the body and oil pool being kept at about 37°C with a heating pad and an infrared lamp. The animal was then immobilized by intravenous injection of gallamine triethiodide (Gallamine, Teisan, Co.) and respired artificially. Bilateral pneumothorax was performed in some cats when respiratory movement of the spinal cord disturbed the recording.

Stimulation and Differential Blocking

Several methods for differential blocking of nervous conduction of larger fibers have been reported (Mendell and Wall, 1964; Zimmermann, 1968; Manfredi, 1970). After we tested these methods, we have developed the following method for differential blocking of larger fibers. As shown in Fig. 1, the gastrocnemius nerve was mounted on silver bipolar stimulating electrodes (interpol distance 9—10 mm) and on polarizing electrodes of cotton thread soaked with physiological saline solution. One of the polarizing electrodes was arrayed proximal to the stimulating electrodes and the other one was arrayed distal to them (interpol distance about 20 mm). These polarizing electrodes were connected to a trapezoid wave current generator, the proximal electrode being positive and the distal one negative. The generator was adjusted so as to produce a current rising linearly up to 60 μA in 5 sec, as shown in lower right inset of Fig. 1. During the rising phase a square wave pulse (0.05 msec in duration and 10—15 times the strength of the lowest threshold motor fiber) was applied to the nerve at a frequency of 1 Hz. By this method larger motor fibers are selectively and gradually blocked, as shown in Fig. 1A—E. When the polarizing current was raised too steeply the current itself has a stimulating effect on the nerve, but when it was raised in 5 sec as described above no such activation was observed and satisfactory blocking of nerve conduction was obtained. This differential blocking was obtained repeatedly without any signs of deterioration of the nerve fibers. Moreover, when experimenters wanted to get a certain level of blocking, for example at the level of Fig. 1B, it was possible to do so by stopping the rising of the current and maintaining the DC level. The antidromic motor nerve volleys were usually recorded from a fine rootlet at the exit of dural cavity as illustrated in Fig. 1. By this method, however, only a small part of the motor nerve volley is observable. Therefore in several experiments an extra recording electrode was placed under the gastrocnemius nerve at the popliteal fossa about 4 cm proximal to the stimulating electrodes and the differential blocking was observed both on the whole nerve at the popliteal fossa and on the rootlet. Always these observations yielded a parallel blocking.

In the present experiment only the gastrocnemius nerve was investigated, because the present blocking method could be successfully applied only to those nerve bundles having a thickness such as that of the gastrocnemius nerve, and when thicker nerve bundles were investigated satisfactory blocking was not always possible.

Recording from Renshaw Cells

The activity of Renshaw cells was recorded extracellularly, in the L7 and S1 segments of the spinal cord, by the usual glass microelectrodes filled with 1 M NaCl solution and having