An Investigation Concerning the Restitution of Motor Function Following Injury to the Spinal Cord

JOHN A. JANE, M.D.,* JOSEPH P. EVANS, M.D., AND LESTER E. FISHER, D.V.M.†
Department of Neurosurgery, University of Chicago Clinics, Chicago, Illinois

The nearly complete restitution of motor function that is observed in a wide range of experimental animals including rodents,17 carnivores,1 and primates10,14 following lateral hemisection of the spinal cord has prompted study of the mechanisms and pathways that are responsible. Two major features of this recovery remain obscure. First, what motor fibers are involved? The corticospinal tract and reticulospinal and propriospinal system represent two possible and not necessarily mutually exclusive ways in which efferent impulses may be carried to the limbs ipsilateral to the hemisection. Second, does the functional connection between the sides of the cord take place between each segment or at one specific location?

Mettler14 has approached these problems by performing cervical hemisections and allowing recovery to take place. Cortical ablations were then performed on the side contralateral to the cord lesion. A hemiparesis contralateral to the cortical lesion and on the same side as the cord lesion was attributed to late crossing pyramidal fibers. Lassek and Anderson’s10 investigation was based upon crossed hemisection in 7 Macaca mulatta, of which none showed significant recovery.

In the present study crossed hemisection, i.e. left lateral section at one level and right lateral section at another, were made in a series of 19 cats, 7 of whom showed considerable restitution of motor function (Figs. 1 and 2). This paper reports these results and their implication for spinal-cord function, particularly recovery of function, based upon histological examination of the cord lesions.

Materials and Methods

A total of 19 cats was used. The hemisection or sections were lateral, being achieved through a standard laminectomy of one to three vertebrae. The dura mater was left open and Gelfoam was placed in the lesion. Three to 8 weeks were allowed for recovery from the first hemisection. The second hemisection was then performed. In most preparations the higher section was performed as

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* Present address: Illinois Neuropsychiatric Institute, 912 S. Wood St., Chicago 12, Illinois.
† Address: Director Lincoln Park Zoological Gardens, Chicago, Illinois.
the first procedure but the reverse was also attempted with no apparent difference in results. Following completion of the experiments the entire body was perfused with normal saline followed by isotonic formaldehyde. The spinal cord was removed and the lesions were examined in serial section. Hematoxylin and eosin and Klüver-Barrera stains were employed most frequently but in some cases Weil and thionine stains were used.

The maximum extent of the cord lesions is diagrammatically reconstructed in Figs. 3 and 4. Densely gliosed nervous tissue has been considered to be nonfunctional although strictly speaking this may not be true. Usually these borderline areas of recognizable nervous tissue adjacent to dense mesenchymal scar are quite thin and do not appreciably affect the total area involved.

Results

1. The first hemisection produced a profound ipsilateral flaccid paralysis below the site of the lesion which usually began to improve within 3 days. Maximum recovery was attained between 3 and 8 weeks and at this time the second hemisection was performed.

2. In all cases the second hemisection resulted in bilateral flaccid paralysis of the lower extremities. If recovery took place it ordinarily began within 1 week of the second procedure.

Seven cats recovered function to the extent of being able to walk and climb up on a 10" ledge and jump from it (Figs. 1, 2 and 3). These animals showed residual weakness which was more severe distally. It was necessary to express their bladders manually 1 to 3 times each day.

3. Before perfusion was carried out in these animals that had recovered, a complete transection of the spinal cord was performed just above the highest lesion. This was done to rule out the possibility that the motor function observed was produced by the spinal cord alone and was a form of "spinal walking." In each case paraplegia resulted from transection, indicating that supraspinal structures were involved in the recovery of function. These animals were observed from 1 to 3 days during which time no recovery was apparent. Another indication that the function was under supraspinal control is furnished by experiments to be reported in which cortical sensorimotor ablations were made following crossed hemisections. A predominantly crossed paresis resulted from these cortical lesions, again implicating supraspinal control of motor function.

Summary of Results and Interpretation of Histology

1. A single hemisection at the cervical or thoracic level is followed by nearly complete recovery.

2. A second hemisection performed 3 to 14 segments below or above the first but on the opposite side is followed by bilateral paralysis.

3. Function is not recovered if at either level of section the ventral columns are interrupted on both sides.

Discussion

In order to explain recovery in the bilateral crossed hemisections the remaining nervous tissue in the cord must have the following characteristics. First, there must be a diffuse system with frequent crossings capable of