Peripheral Nerve Implantation in Experimental Paraplegia*

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At present, the concept of "abortive regeneration" in the central nervous system of mammals is no longer tenable.22,23 Many investigators have demonstrated that elements of the mammalian central nervous system are capable of regeneration,2,3,19 which process can be enhanced by treating the lesion with trypsin,4 roentgen-ray radiation,23 or by the administration of systemic pyrogens.6,10,14,24 As a rule, regeneration of traumatized central axons in the spinal cord proceeds under optimal conditions, viz., clean surgical lesion, vascular integrity, hemostasis, early approximation of severed ends and excellent physical condition of the animal. It is apparent that such an ideal milieu for neurofibrillar neoformation is seldom if ever present in traumatic paraplegia as encountered in clinical practice. Therefore, it is not surprising that re-establishment of functional continuity between the completely transected segments of the spinal cord by means of regenerating central neurofibrils has never been unequivocally demonstrated in man.3,22

The use of centrally connected implants of peripheral nerve into the distal segment of the transected spinal cord offers an inviting alternative for establishing neuronal continuity between the proximal and distal stumps of the severed spinal cord.5,30 In the present experiment intercostal nerves or sympathetic-nerve trunks were used as implants and their effect on the functional performance of paraplegic dogs was studied.

Methods and Materials

Thirty-nine adult mongrel dogs of both sexes were used. The animals were separated into three major groups.

Group I—Controls.
   a) Sham controls 2 dogs
   b) Controls 4 dogs

Group II—Sympathetic nerve-trunk implantation.
   a) One-stage 11 dogs
   b) One-stage treated with ethanolamine-1,2 10 dogs
   c) Two-stage 2 dogs

Group III—Single and multiple intercostal-nerve implants.
   a) Single 1 dog
   b) Bilateral 7 dogs
   c) Triple 2 dogs

Laminectomy was performed extending from T10 to T12. In sham controls, the operation was terminated at this stage, while in controls the dura mater was incised longitudinally and a 1-cm. segment of spinal cord was removed. The dural edges were approximated but were not sutured.

For implantation of a sympathetic nerve laminectomy with excision of a cord segment was followed by subperiosteal resection of ribs T11 and T12. Epipleural dissection of the sympathetic trunk was carried out caudad for 7 to 10 cm. The rami communicantes were cut and the trunk was divided; the free end of the centrally connected sympathetic nerve was next drawn through the longissimus dorsi muscle into the site of the laminectomy and implanted in the distal stump of the transected spinal cord by means of a 6 O silk guide suture (Fig. 1). In the two-stage operation (Group II c) the sympathetic trunk was inserted into the intact spinal cord. Two months later the segment of spinal cord was excised proximal to the site of implantation. Ten dogs of the sympathetic-
implant group were treated postoperatively with subcutaneous injections of ethanolamine-1,2 for 30 consecutive days, dosage being 20 mg./kg. of body weight.

The intercostal nerves to be implanted were dissected 1 segment above the level of the spinal cord transection. A 5–7 cm. portion was freed and divided, and the end of the central segment was inserted in the distal stump of the spinal cord as described previously (Fig. 1).

The dogs were observed from 100 to 285 days. Weekly neurological examinations were carried out to assess the reflex activity and locomotor function of the animals and observations were recorded on individual charts of performance.

In 6 dogs of Group II and 2 dogs of Group III the nerve implant was sectioned subsequently from 103 to 208 days after operation. Electrophysiological studies were performed on 13 treated dogs as well as on normal animals. These consisted of recording spontaneous electrical activity and induced action potentials resulting from stimulation of the implanted nerve.

At the completion of the experiment the dogs were sacrificed by means of a lethal dose of pentobarbital sodium and were perfused using a pulsatile perfusion-fixation technique. Serial sections of the spinal cords were stained with Bodian’s protargol method and a variety of other stains.

Observations

1) Function. The following grading was employed for the evaluation of reflex and locomotor activity:

a) Locomotor function.
- Hind legs of the animal unable to support the weight of the body when the animal is placed in the standing position.
- Hind legs can support superincumbent weight of body when animal is placed in the standing position.
- Animal able to stand unassisted.
- Animal able to stand unassisted; walks short distances. Front and hind limbs not co-ordinated.
- Co-ordinated walking ability.

N Normal locomotion.

b) Reflex function; spasticity.
- Failure to elicit reflex; markedly diminished tonus.
- Normal reflex; normal tonus.
- Increased reflex activity; medium spasticity.
- Hyperreflexia; hyperspasticity.

Group I (Controls). In sham control dogs no neurological deficit was present. In other control animals, following spinal shock, depressed reflex activity was observed for a period varying from 1 to 6 weeks during which time these dogs also exhibited the Schiff-Sherrington phenomenon. Subsequently there developed a pronounced hyperreflexia and spasticity: foot drop, exaggerated segmental flexion and brisk tendon reflexes were seen in all animals. There was a marked variation in locomotor recovery of the control animals. The lowest level of functional attainment was represented by dogs that were unable to support their paralyzed body segment when placed in the standing position. These animals moved about by dragging their paralyzed limbs which were either extended completely or hyperabducted. Spasticity in the hind limbs was considerable and often arthrodesis of the hyperextended limbs developed despite physiotherapy. In contrast, 2 of the control dogs were observed to stand up unassisted and to take a few steps. These dogs initiated locomotion by straining forward and by flexion of the neck. The paralyzed portion of the body was next visibly raised off the ground mainly