Repair of ruptured spinal nerve roots in a brachial plexus lesion

Case report

THOMAS CARLSTEDT, M.D., PH.D., AND GEORGE NOREN, M.D., PH.D.

Departments of Orthopaedics and Neurosurgery, Karolinska Hospital, Stockholm, Sweden

A 22-year-old woman sustained a brachial plexus injury with supraganglionic rupture of the C-8 and T-1 nerve roots as a result of a traffic accident. She was operated on approximately 1 week following the accident. After a hemilaminectomy, the intradural defects in the ruptured roots were bridged with sural nerve grafts. Within 3 years she recovered function in all muscles supplied from the lower roots in the plexus except for the intrinsic hand muscles, but she had a persisting, complete sensory loss in the ulnar nerve distribution. The possibility for functional gain after repair of spinal root lesions in brachial plexus patients is discussed.

KEY WORDS • spinal nerve root • brachial plexus • nerve repair

BRACHIAL plexus injury is usually complex, involving both spinal nerve and spinal root ruptures, together with avulsion of one or several roots from the spinal cord. The nerve ruptures can be managed according to routine surgical principles for peripheral nerve injuries with some functional outcome. On the other hand, supraganglionic or nerve root injury is considered a type of central nervous lesion and, hence, not amenable to operative repair. Experimental evidence from different mammals has shown anatomical and functional regeneration of motor fibers after coaptation of severed ventral roots. Recently, in a primate study, it was shown that repair of the intraforaminal portion of spinal nerves to the brachial plexus resulted in adequate regeneration with return of muscle function.

The return of function after repair of spinal nerve roots would have considerable clinical potential in the management of brachial plexus injuries. We therefore applied a proximal surgical strategy in a patient who suffered intraspinal rupture of roots to the brachial plexus. The functional outcome after surgical treatment of the ruptured spinal nerve is described and discussed.

Case Report

This 22-year-old woman was involved in a traffic accident and sustained multiple trauma. She had been hit by a board on the lower right side of the neck.

Examination. Physical examination revealed that the patient had a right-sided hemothorax, a crush fracture of the right first rib, fractures of the right transverse processes of the C-7 and T-1 vertebras as well as a brachial plexus injury. The whole plexus was involved in the lesion; there was Horner’s syndrome and paralysis of the muscles in the right arm innervated by the C7–T1 roots. She could not flex or extend the wrist or the fingers. There was considerable weakness in shoulder and elbow motion (C5–7). She had no sensation in the ulnar region of the hand and arm (C8–T1 dermatomes), reduced sensation in the third finger, but normal sensory function in the two radial fingers (C-6 dermatome).

Operation. The patient was operated on 8 days after the accident. The proximal portion of the brachial plexus was reached through a modified (midline incision) posterior subscapular approach. Spinal nerves C5–7 were in continuity to the intervertebral foramen. The C-8 and T-1 nerves were torn out from the intervertebral foramina. Electrical stimulation of the C5–6 spinal nerves yielded a prompt and vigorous muscle response. No activity could be elicited after stimulation of the C7–8 or T-1 spinal nerves. Stimulation of the exposed C5–6 nerves elicited sensory evoked potentials, but no response was seen when stimulating the C7–8 and T-1 nerves. The spinal nerve roots C7–8 and T-1 were exposed through a posterior laminectomy.

A right-sided hemilaminectomy of C7–T2 including facetectomy at C6–7 and C7–T1 revealed that the C-7 roots were in continuity, but that the C-8 and T-1 roots had ruptured proximal to the foramina (Fig. 1 left). Several of the fascicles were avulsed from the spinal cord. The C-8 and T-1 ventral roots were reconnected to their spinal nerves by sural nerve grafts harvested from the lower extremities by several transverse skin incisions. The spinal root ruptures were bridged using four grafts approximately 7 to 8 cm long (Fig. 1 right). These were coapted to the proximal ends of the C-8 and T-1 roots in the spinal
canal, pulled ventral to the paravertebral muscles, and attached to the distal stumps of the ruptured roots. The position of the grafts was secured by using Tisseal tissue glue. Before closing the wound, stability in the cervical spine was tested.

Postoperative Results. Nine months after surgery a generalized muscle atrophy was seen in the right arm. There was a full range of movement in the shoulder and elbow joints, but the strength in the biceps muscle was considerably less compared to the uninjured side. Flexion and extension in the wrist had returned as evidenced by activity in the extensors to the wrist and the radial flexor. No clinical activity was noted in the ulnar wrist flexor. There was no activity in the finger extensors and the abductor to the thumb, but slight twitches of flexion could be noted in the superficialis muscles to the second and third fingers. Electromyography showed denervation activity in the ulnar wrist flexor, the flexor profundus muscles to the ulnar fingers (Fig. 2a), as well as the intrinsic muscles of the hand. Denervation activity together with occasional voluntary activity was seen in the finger extensors. Reinnervation was seen in muscles proximal to the elbow. Sensory loss was limited to the area for the ulnar nerve.

Eighteen months after surgery, strength in wrist extension and flexion had improved. Muscle activity had returned in the ulnar wrist flexor as well as in the profundus muscles to the three ulnar fingers. Some activity was noted in the finger extensors, but not the thumb. There was still no activity in the intrinsic hand muscles. Electromyography showed reinnervation in forearm muscles, except for the intrinsic hand muscles. There was a total loss of sensibility in the ulnar nerve region.

Two years after surgery there was full muscle power in the shoulder as well as in elbow flexion, but somewhat reduced activity in elbow extension. Power in wrist extension was reduced and finger extension was weak. There was full power in finger flexors except to the first and second fingers. There was still no intrinsic activity and the sensory function had not improved.

Three years after surgery there was full activity in the shoulder, elbow, and wrist. There was full power in flexion of the three ulnar fingers, but reduced flexion activity in the index finger. Electromyography showed reinnervation potentials in the flexor digitorum profundus, the ulnar wrist flexor, and finger extensor muscles (Fig. 2b). The fingers could not be extended with the wrist in the neutral position (Fig. 3). Sensory activity was absent in the ulnar nerve territory by both clinical and neurophysiological testing.

Discussion

Functional restitution after coaption of severed ventral roots has been reported in several mammals. A dorsal root, when damaged central to its ganglion, regenerates to the spinal cord but does not enter it. Thus, sensory function will not reappear after root repair. However, the ventral spinal nerve root, being the first extramedullary part of the spinal cord motor neuron, can be expected to regenerate analogous to the peripheral nerve.

This patient sustained a traction injury to the most proximal part of the brachial plexus, giving rise to a “classic” type of injury: partial lesion (neuropraxia–neurotmesis) of the upper part of the brachial plexus and ruptures (neurotmesis) of the lower roots (C-8 and T-1). The expected outcome of spontaneous recovery would be return of function in relation to the severity of the lesion. Thus, the best function could be expected in proximal muscles innervated from the C-5 and C-6 spinal nerves and no functional recovery from lower roots C-8 and T-1.

As expected, the upper parts of the plexus recovered spontaneously to almost full activity within a year after the accident. However, muscles in the forearm, such as extrinsic finger flexors innervated from the repaired lower roots, also showed a considerable functional improvement after 2 to 3 years. Muscle power was even greater in those muscles than in muscles innervated from intermediate (C-7) roots, for instance finger extensors. Thus, a robust functional improvement had occurred in the forearm muscles regularly innervated from the C-8 and T-1 spinal nerves. Total interruption of neuromuscular connectivity had been demonstrated by neurophysiological means in those muscles and ongoing reinnervation was seen even 3 years after surgery (see Fig. 2a).

Some of the muscles that have recovered function, such as extrinsic finger flexors, are usually considered not to be innervated from spinal nerves other than C-8 and T-1. The segmental innervation of individual muscles is, however, by no means settled. Variations in the general pattern of the plexus, anomalous communications between the nerve roots of adjacent spinal cord segments, and the pre- and postfixation of the plexus make determination of how...
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much of any improvement can be attributed to surgery most uncertain. The recovery of function could therefore very well depend on reinnervation from other, nonrepaired sources, such as the C-7 root. The remaining impaired sensory function in the ulnar nerve territory, together with improved muscle activity within the region supplied by the lower roots in the plexus, indicates that the repair of the supraganglionic nerve root lesion had an effect on the recovery of motor function.

Intrinsic hand muscles did not recover. This is the usual outcome after repair of more distal lesions, for instance, the medial trunk or the ulnar nerve. The absence of recovery in the intrinsic hand muscles is considered to be an effect of an unfavorable time–distance factor,7,8 that is, too long a distance across which the nerve fibers must regenerate.

Experimental studies in primates have demonstrated functional improvements depending on repair of the most proximal parts of spinal nerves,9 as well as of ruptured spinal roots, and even after avulsions from the spinal cord.3 Thus, it has been shown that after a repair in the intraforaminal part of spinal nerves to the plexus, more or less adequate levels of regeneration were noted throughout the shoulder, arm, and hand muscles in primates.3 This case, with injuries similar to those described in the primate experiments, provides a clinical application of a new surgical strategy to manage proximal spinal nerve or spinal root lesions in brachial plexus injuries. This surgery requires laminotomy and facetectomy, which is of some concern because of the possible development of secondary scoliosis and/or cervical spinal instability. Stabilization of the cervical spine was not performed in this case after the removal of two laminae and two intervertebral joints. No clinical or radiological signs of morbidity occurred, however.

Previous experimental studies on surgical treatments of injuries in the most proximal part of spinal nerves as well as spinal nerve roots have produced encouraging results. It has been shown that these lesions in fact are possible to treat with a functional outcome. The application of these experimental strategies in a human case led to improvement of muscle activity, but sensory function remained impaired. These results indicate that the concept that supraganglionic lesions are not amenable to surgery is not valid for ventral root injury. Although the outcome of surgical treatment for spinal nerve root severance in this patient seems promising, the nature of lesions in clinical cases is generally not as discrete and defined as in experimental situations. The extent to which the improvement can be attributed to repair versus spontaneous recovery can therefore be difficult to appreciate in a single case. A series of patients is needed to accurately define the effect of this type of surgery in humans.

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References


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Address reprint requests to: Thomas Carlstedt, M.D., Department of Orthopaedics, Karolinska Hospital, S-17176 Stockholm, Sweden.