# ROLE OF MICROSURGERY IN REPAIR OF PERIPHERAL NERVE INJURIES OF THE UPPER EXTREMITY

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BY

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A peripheral nerve consists of two types of tissues; those that can conduct an impulse and those that cannot. The fundamental structure involved in impulse conduction is the axon. Axons may be myelinated or unmyelinated, a characteristic that affects their conduction velocity, susceptibility to and recovery from injury.

Individual axons vary from a few millimeters to a meter in length and from 0.3 to 25 u. in diameter and are never seen by a surgeon in the course of an operation (**Sunderland 1978**).

Contained in the axoplasm are neurotubules and neurofilaments which represent the main constituents, and also, mitochondria, endoplasmic reticulum and granular and vesicular structures (**Sandborn et al., 1964, Peters et al., 1970, Webster 1974, 1975**). They are involved in the growth, elongation and maintenance of the elongated form of the neural processes as well as in the bidirectional transport of materials along the axons.

Connection with the cell body is a prerequisite on which the life of the axon depends. This vital relationship is associated with an intracellular pressure which is reflected in the outflow of axoplasm which occurs when the nerve fibre is severed **(Young 1945)**, in the behaviour of nerve fibres subjected to circumferential pressure **(Causey 1948)**, by swelling which appears proximal to the constriction of a nerve fibre **(Weiss 1943, 1961, Friede and Miyagishi 1972)** and the asymmetry of the bulbous enlargements of the axon on both sides of a node **(Lubinska 1954, Lubinska and Lukaszewska 1956)**.

Axoplasmal flow and axon transport (both fast and slow transport systems) are established now. Axon transport is bidirectional **(Barondes 1969, Weiss 1972, Ochs and Jersild 1974, Ochs 1975)**. It is now clear that nerve impulses are not the only traffic travelling along nerve fibres, for the axon also represents a channel along which a great variety of cell constituents are continually on the move, using fast and slow peripheral and retrograde transport mechanisms to reach their destination and produce their effects. That the survival and welfare of the axon and the structures it innervates depend on these transport mechanisms seems clear even if it is not known how this is effected **(Sunderland 1978)**.

The multilayered sheath, in the case of myelinated nerve fibres, consists of a Schwann cell-myelin complex internally and a connective tissue layer externally, the two being separated by a basement membrane.

Immediately surrounding the axon is a layer of myelin which, longitudinally, is broken into segments. This segmental arrangement outlines the nodes and internodes of the nerve fibre. Investing the myelin, and intimately related to it, is a single layer of flattened Schwann cells which, at each node, reaches and embraces the axon which constricts at this site. Each internode carries one Schwann cell nucleus which is situated approximately midway between adjacent nodes and indents the subjacent myelin.

External to the Schwann cell layer is a basement membrane and beyond this, a fine investment of connective tissue, which is the endoneurium.

**Peripheral nerve trunks :**

In their passage to the periphery nerve fibres do not run independent courses as single units but are collected into bundles or funiculi with which are associated other tissues and structures to form the peripheral nerve trunks.

The component parts of nerve trunks are :

1- Nerve fibres

2- Funiculi

3- Connective tissues

4- Blood vessels

5- Lymphatics and tissue spaces

6- Nervi nervorum

**Funiculi :**

The perineurium is a distinct, identifiable layer,visible to the eye which encases a group of axons to form a funiculus (Synonym : fascicle).

It is uncommon for human peripheral nerves to be composed of a single funiculus. They are, on the contrary, usually composed of several funiculi which, by repeatedly uniting and dividing, engage in plexus formations along the full length of the nerve **(Sunderland 1945, Sunderland and Ray 1948, Sunderland et al., 1959).**

Funicular plexuses result in rapid changes in the funicular pattern. The maximum length of nerve with an absolutely constant pattern is approximately 15 mm though individual bundles or bundle groups pursue longer courses.

In some regions of certain nerves the fibres may be collected into a single funiculus. Examples are the uluar nerve behind the medial humeral epicondyle, the radial nerve in the spiral groove, the lateral popliteal nerve in the distal fourth of the thigh and the axillary nerve beneath the shoulder joint.

**The connective tissues of peripheral nerve trunks :**

A peripheral nerve trunk consists of nerve fibres, each enclosed in an endoneurial sheath, which are bound together into bundles or funiculi by the perineurium. These funiculi are, in turn, embeded in an areolar connective tissue framework, which is the epineurium. The endoneurium, perineurium and epineurium constitute the connective tissues of peripheral nerves.

**1) The epineurium**

The epineurium both encircles the entire nerve and separates those bundles within. It consists of loosely arranged, randomly oriented bundles of collagen.

Normal epineurium is quite resilient. It can slide back and forth on the bundles within it, as well as move independently within its surrounding soft tissues.

The elasticity of its fibres contribute to the slack of the slightly tortuous course of the peripheral nerves in their beds.

**2) The perineurium**

The perineurium consists of several bands of collagen, arranged in longitudinal, transverse and oblique lamellae. This configuration gives it great strength and makes it an easily identifiable layer. On its inner surface, the perineurium is quite distinct from endoneurium, but its outer surface blends gradually into the epineurium. The natural plane of surgical dissection within a nerve is between epineurium and perineurium.

The perineurium serves an important biochemical and mechanical role. It serves as a differential diffusion barrier to help maintain both the correct ionic concentration and a positive axoplasmic pressure within the funiculus. Thus, during intraneural dissection and identification of separate bundles for their subsequent suture, it is critical to recognize that the integrity of the perineurium is paramount and should not be violated, if at all possible.

**3) The endoneurium**

The endoneurium provides the packing inbetween individual nerve fibres around each of which it forms a delicate external layer. Its principle function is to maintain the internal millieu of the working part of the nerve. Its integrity is essential to normal function.

Nerve fibres run slightly undulating courses inside the funiculi so that, when nerve trunks are stretched, the nerve fibres do not commence to share the load until stretching reaches the point where these undulation are eleminated.

Concerning the individual components of the nerve fibre itself, the evidence favours the conclusion that the endoneurium is the tissue resisting elongation under tension. The endoneurium, however, is not as strong as perineurial tissue, so that, though the endoneurium has strength and elasticity, nerve fibres are more vulnerable to stretch and compression where they eack their protective epineurial and perineurial sheaths.

Thus a comparison of values for strength and elasticity of spinal nerve roots and peripheral nerves trunks indicates that the former fail under tension before the latter **(Sunderland and Bradley 1961)**; the perineurium is absent in nerve roots but forms a conspicuous component of peripheral nerve trunks. Furthermore, the collagen fibres covering the nerve fibres of nerve roots are fewer and finer than those surrounding nerve fibres in peripheral nerve trunks **(Gamble 1964)**.

**The blood vessels of peripheral nerve trunks :**

Peripheral nerves are abundantly vascularized throughout their length by a succession of vessels which, by their repeated division and anastomosis within the nerve, form an unbroken intraneural vascular net **(Sunderland 1945).** With the exception of the median and sciatic arteries, no vessels larger than arterioles are found in peripheral nerves.

The arteriae nervorum, which are vessels that enter the nerve and terminate intraneurally, are derived, in an inconstant manner, from arteries that are intimately related to the nerve, or which, at most, are not far distant from it.

The vessels usually take the most direct route to the nerve. On reaching the nerve, the arteriae nervorum may terminate in many different patterns.

As a result of the rich longitudinal intraneural anastomotic vascular systems, a considerable length of a nerve trunk can be resected from its bed without disturbing the blood supply to the nerve, or without adversly affecting the structure and function of nerve fibres or their regeneration below a crush injury **(Adams 1943, Lundborg and Branemark 1968, Lundborg 1970).**

The intraneural venous pattern corresponds to the arterial arrangement. Venules and arterioles do not always run together and they may differ in number and vessels to which they drain and originate from.

Of interest is the effect of stretch on blood supply. **Lundborg (1977, 1979)** noted in the sciatic nerve of rabbit that as little as 8 percent elongation was sufficient to compromise intraneural veneular flow and that 15 percent elongation was sufficient to stop intraneural flow. While the percentages may not be applicable to humans, it is likely that the effect of stretch on blood supply is similar. This evidence further suggests that tension should be avoided in nerve repair, not only because of its effect on conduction, but on blood supply as well. **(Jabaley, 1983)**

**The Mechanical properties of peripheral nerve trunks :**

Peripheral nerves possess elasticity. When a nerve is subjected to a gradually increasing tensile load, there is a linear relationship between load and elongation until a certain point is reached after which proportionality no longer holds, and the elasticity of the nerve has broken down. The nerve now passes into a semi-plastic state so that further application of load causes the strain to increase more and more rapidly with the stresses until a value of load is reached at which local yielding of the nerve occurs.

Despite the considerable range of individual variation, (according to the individual, the nerve and the level along the nerve) the greatest elongation at the elastic limit being in the order of 20 percent; complete mechanical failure occurs at maximal elongation of approximately 30 percent **(Sunderland 1978).**

Physiological failure, on the other hand, occurs at or just below the elastic limit. Figures were given between 6 percent **(Liu et al., 1948** in man), 11 to 18 percent **(Lundborg and Rydevik, 1973** in rabbit) conflicting with data reported by **Denny-Brown and Doherty** (1945, 100 percent, cat) and **Haftek** (1970, 69.3 percent, rabbit).

According to **Sunderland and Bradley (1961)** elasticity and tensile strength reside in the funicular tissue and, in particular, the perineurium. The general conclusion is that the funiculi and their contained nerve fibres are protected against compression by a cushion of epineurial tissue and against tension by the perineurium and endoneurium.

That nerve fibres do not contribute to the tensile strength of nerve trunks is suggested by the observation that the denervated distal segment of a severed nerve has the same tensile strength and elasticity as the normal proximal segment **(Sunderland and Bradley, 1961)**.

**Sunderland and Bradley** (1961) have shown that spinal nerve roots have strength and elasticity, though they lack epineurial and perineurial tissue, by their endoneurial covering. Nevertheless, nerve fibres are more susceptible to mechanical damage where the epineurium and perineurium are absent. A further point of weakness is that the root fibres run in parallel non-plexiform bundles. It is for this reason