Peripheral nerve repair

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Peripheral nerve repair refers to the surgical procedures and techniques used to treat damage to the peripheral nervous system (PNS), which includes all the nerves outside the brain and spinal cord. The PNS is responsible for transmitting signals between the brain and the rest of the body.

The repair of peripheral nerve damage can be approached in several ways, depending on the severity and location of the injury. The primary techniques for peripheral nerve repair include:

1. **Nerve Suturing (Direct Repair):** For clean, non-crushed nerve injuries where the nerve ends are close together, the surgeon may perform direct nerve suturing to reconnect the severed ends. This is the most straightforward method, but success depends on the precise alignment of the nerve fibers.

2. **Nerve Grafting:** When the nerve ends are far apart, or when there is a large gap, nerve grafting may be necessary. In this procedure, a segment of nerve from another part of the body (often the sural nerve) is used to bridge the gap between the severed ends of the damaged nerve.

3. **Nerve Transfers:** In some cases, nerves that are not vital to a particular function may be used to restore function to a damaged nerve. This is known as a nerve transfer, where a healthy nerve is re-routed to replace the function of a damaged nerve.

4. **Nerve Conduits (Tubular Repair):** In cases of smaller nerve gaps, a nerve conduit or tube may be used to guide the regenerating nerve fibers. These conduits can be made from synthetic materials or biological substances and promote nerve regeneration across the gap.

5. **End-to-end Anastomosis:** This technique is used for smaller, less complex injuries. The two ends of the nerve are carefully aligned and sutured together without the need for a graft or conduit.

6. **Autologous Nerve Grafts:** When a nerve graft is necessary, using a patient's nerve tissue (autologous graft) reduces the risk of rejection and provides the best biological match for nerve repair.

Post-surgery rehabilitation is crucial for nerve repair success. It often involves physical therapy to improve muscle strength, coordination, and functionality of the affected area.

The outcome of peripheral nerve repair depends on factors such as the type of injury, the time elapsed between injury and repair, the nerve's ability to regenerate, and the skill of the surgeon. Even with successful repair, full recovery may not always be achieved, and some patients may experience residual weakness or sensory loss.

When a peripheral nerve is injured, signals to and from the brain can be disrupted and normal body functions may be lost. Peripheral nerves have the ability to regenerate and heal themselves depending on the severity of the damage. A crushed or compressed nerve may be able to heal on its own while a nerve that has been completely transected will need surgical intervention to help in reconnecting the axons to their targets.

Transected Nerves

When a peripheral nerve is cut, it is separated into two parts, the proximal part and the distal part. The proximal side of the nerve is closest to the spinal cord and is still in communication with the central nervous system (brain and spinal cord). The distal side of the nerve is farther away from the spinal cord and has lost communication with the central nervous system. Once severed, the axons in the distal nerve begin to break down and the body sends special cells to clear the resulting cellular debris. This process is called Wallerian degeneration and leaves relatively hollow tubes in the nerve where the axons used to be.

Following the injury, specialized cells called Schwann cells proliferate from both the proximal and distal nerve stumps to support regeneration. The proximal end of the nerve fiber begins to sprout toward the distal nerve. The nerve fiber advances at about 1mm per day and may eventually reach its target tissue where it can once again provide sensation or movement.

Surgery to repair severed nerves is done to help contain or guide the nerve sprouts to the distal end of the nerve. Without guidance, these sprouts can potentially form a neuroma or die back into the proximal nerve. You can find more information about the treatment of severed nerves here.

Compressed or Crushed Nerves

When a nerve is crushed or compressed the signals that flow through the axon are disrupted and may not reach their target organ. This can lead to pain, numbness, or loss of functionality. Depending on the severity of the compressed or crushed nerve, it may be able to regain functionality without surgical intervention. The force that caused the crush or compression should be eliminated to relieve pressure and allow healing to begin. After nerves are crushed, they may become replaced with scar tissue which can hinder nerve recovery and can require surgery to remove the scarred part of the nerve. In less severe cases, where there is little or no scar formation within the nerve, the injury can potentially recover from the compression or crush and regain normal function without surgical intervention.

Challenges in Peripheral Nerve Repair

- **Regeneration Limits**: Unlike central nervous system (CNS) neurons, peripheral nerves can regenerate, but the process is slow, and functional recovery may be incomplete, especially with large nerve defects.

- **Scar Tissue Formation**: After the injury, scar tissue can form around the damaged nerve, hindering regeneration and leading to permanent dysfunction.

- **Long Recovery Times**: Even after successful surgical intervention or grafting, the recovery process can take months or even years, and full recovery may not always be achieved.

Future Directions

Advances in tissue engineering, stem cell therapy, and bioengineering offer exciting possibilities for improving the outcomes of peripheral nerve repairs. Strategies such as 3D-printed nerve scaffolds, nerve growth factor therapies, and the use of bioactive materials to encourage nerve regeneration are actively being researched to enhance functional recovery and reduce the time required for nerve repair.

In summary, peripheral nerve defects pose significant challenges in clinical practice, but ongoing research into regenerative therapies and innovative surgical techniques is improving the prognosis for patients with these injuries.

Experimental studies

Peripheral nerve repair experimental studies.

Internal nerve splinting

End-to-end anastomosis of the nerve stump for PNI is well established but cannot efficiently prevent neuroma-in-continuity formation.

Methods: Sciatic nerve injury was used in the experimental model. Seventy-two rats were randomly divided into four groups: rats with nerve anastomosis sites supported with silicone tubes represented the internal nerve splinting (INS) group (n = 18); rats with end-to-end nerve anastomosis represented control group 1 (CON1) (n = 18); rats with INS and the nerve anastomosis site represented control group 2 (CON2) (n = 18); and rats that underwent the same surgical procedures for skin and muscle operations but without sciatic nerve injury represented the normal group (n = 18).

Results: Gross evaluations of the nerve anastomosis sites, gastrocnemius muscle atrophy, Axon regeneration and remyelination, neuropathic pain, and scar hyperplasia of the neuromas were performed, as well as motor function evaluations. Axon regeneration, remyelination, and gastrocnemius muscle atrophy were similar between the INS group and CON1 ($p > 0.05$). However, neuropathic pain and scar hyperplasia-as evaluated according to the expression of anti-sigma-1 receptor antibody and anti-α-smooth muscle actin, respectively-and the weight ratios of the neuromas were reduced in the INS group compared with those of CON1 and CON2 ($p < 0.05$).

Conclusions: Application of INS in nerve repair effectively prevented traumatic neuroma-in-continuity formation and inhibited neuropathic pain without influencing nerve regeneration in rats [1).].

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Luo X, Li B, Zhang D, Chen H, Zhou X, Yao C, Raza MA, Wang L, Tang N, Zheng G, Yan H. A new insight on peripheral nerve repair: the technique of internal nerve splinting. J Neurosurg. 2022 Feb 25:1-12. doi: 10.3171/2022.1.JNS211916. Epub ahead of print. PMID: 35213834.