Nano-Surgery for Axon Repair

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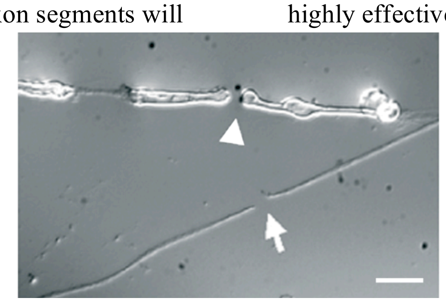
Injury to the nervous system is a common occurrence after trauma. It is well known that nerve cells that are injured, especially those in the brain and spinal cord, are not capable of regenerating circuits to restore neurological function. Injury to the nerves may cause the loss of sensory function as well as motor function.

Researchers for many years have explored whether micro and nanoscale tools can be used to address this major challenge. This research has taken two very different paths. The first is the most traditional and well known research known as axon regeneration. This method involves the development of new nanoscale tissue scaffold materials to create environments that support the growth of new axons. The second path is a relatively new research area involving the physical surgeries of individual axons using micro devices as surgical tools.

Axon nano-surgery conceders nerve injury as a subcellular neurosurgical problem where micro and nano instruments are needed to repair the individual axons. The central thesis of this approach is the physical rejoining of two severed axon segments will restore axon electrical conduction. The main restraint in this research is the technical inability to perform surgical manipulations at a subcellular scale. There has been resent progress in these areas with testing of new technology to perform basic steps of axon repair.



The three basic steps of axon repair include the removal of injured ends of axons and trimming back to healthy axon segments, the alignment of the separated ends of axon, and the fusion of these two ends into a single functioning axon. This abstract focuses on the first step of cutting away the damaged or diseased tissues.

One method uses lasers to cut or ablate axons. This is the most widely explored method. One device, Nano-scissors, have been used to cut whole cells and intracellular elements. This device uses low energy femtosecond laser pulses to create a high photon concentration in small areas without creating a lot of heat that may damage surrounding axons. In the University of Texas, Nano-scissors have been used to cut single axons in nematodes known to allow backwards movement. After the surgery, the nematode was unable to move backwards. About 24 hours later, the axon re-grew and backwards motion was achieved. This shows that the laser was powerful enough to cut the axon but precise enough to avoid harm to surrounding tissue.

A simpler, less costly approach may be mechanical cutting of axons. Specifically, one device known as the Nanoknife has been demonstrated for precise cutting of both CNS and PNS axons in vitro and in vivo. This structure is produced using silicon microfabrication and microassembly techniques. It has two silicon components which includes a microscale cutting structure in the shape of a pyramid and a suspension frame to support the blade and allow flexibility when in contact with hard surfaces. A micromanipulator holds an attached rod in place and delivers a cutting stroke. The blade has a 20nm radius of curvature and can be fabricated from one to hundreds of microns in length.

The Nanoknife has been extensively tested is highly effective in severing both myelinated and umyelinated axons. It is capable of delivering a cut without distorting the adjacent segments and avoids mechanical shearing. It has also been tested in vivo to address whether the micro cutting instruments are effective under real surgical conditions.

This is only the beginning in a long study of axon surgery devices. There are many different techniques still being tested for multiple steps in axon repair. The next step is to bring all these techniques together and demonstrate a successful axon surgery.

References:

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