

Nerve Injuries and Repair as Seen Through Electrodiagnostic Medicine



Improving People's Lives
through innovations in personalized health care

Ultra EMG
February 2013
William S. Pease, M.D.



Wexner Medical Center



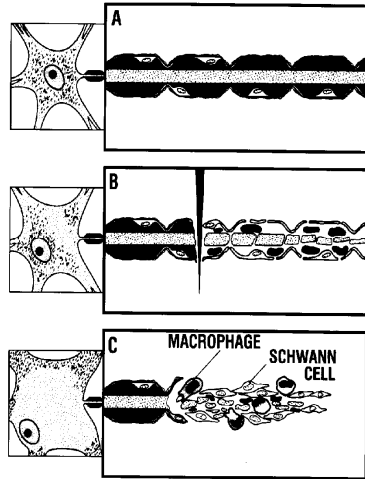
Traumatic
Nerve
Injuries

- An orderly sequence of degeneration and regeneration follows nerve injury.
- Using this knowledge, the electromyographer can make clear statements about diagnosis, treatment and prognosis.



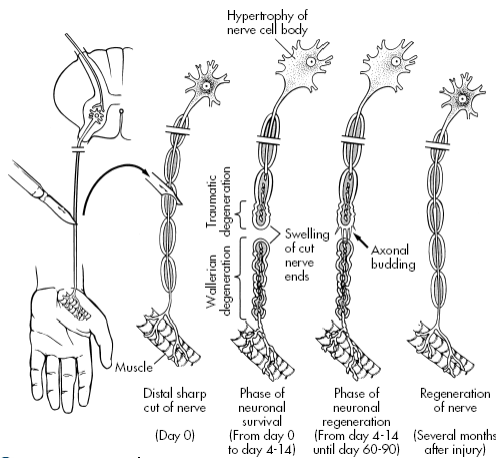
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Traumatic Nerve Injuries Wallerian Degeneration



- Waller 1850
- Axoplasmic fragmentation surrounded by myelin
- Macrophages and (simple) Schwann cells proliferate

Nerve Trauma



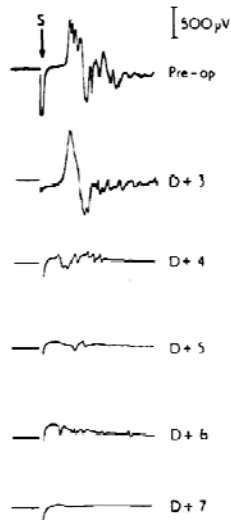
- Retrograde/Proximal changes also occur.
- Neuronal hypertrophy (alpha motor neuron)
- Altered proximal myelin structure

Re-innervation later after Injury

- Sprouts from survivor motor unit axon innervate orphaned muscle fibers
- Larger number of fibers in motor unit
- Higher density of fibers in area, and of same muscle fiber type



EDX Response: Traumatic Nerve Injuries



- 4-5 days - loss of CMAP (NMJ)
- 5-8 days - loss of NAP (axon)
- Response loss is related to length of degenerating nerve stump

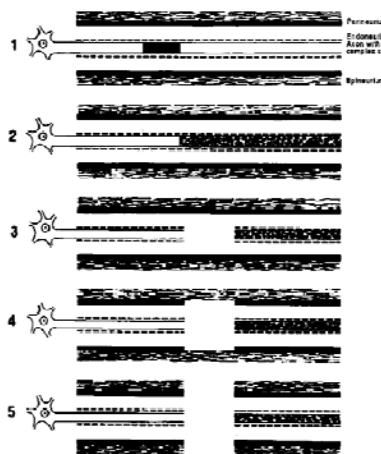


Traumatic Nerve Injuries Changes in Muscle

- Neuromuscular Transmission failure
- Reduced membrane resting potentials
- Increased sensitivity to Acetylcholine away from endplates
- Fibrillation potentials originate near endplate, later at other sites.
- Muscle cells atrophy



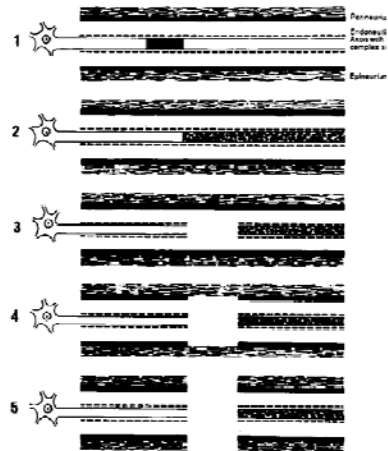
Classification of Injury Cohen-Seddon, Sunderland, Mackinnon



- 1. Neurapraxia (Conduction Block/Myelin)
- 2. Axonotmesis (Axon injury)
- 3. Endoneurial injury (fascicles disrupted)
- 4. Loss of Perineurium (scarring of nerve follows)
- 5. Neurotmesis (Loss of entire nerve continuity)
- 6. Neuroma in Continuity (Mixed pattern 1 thru 5)



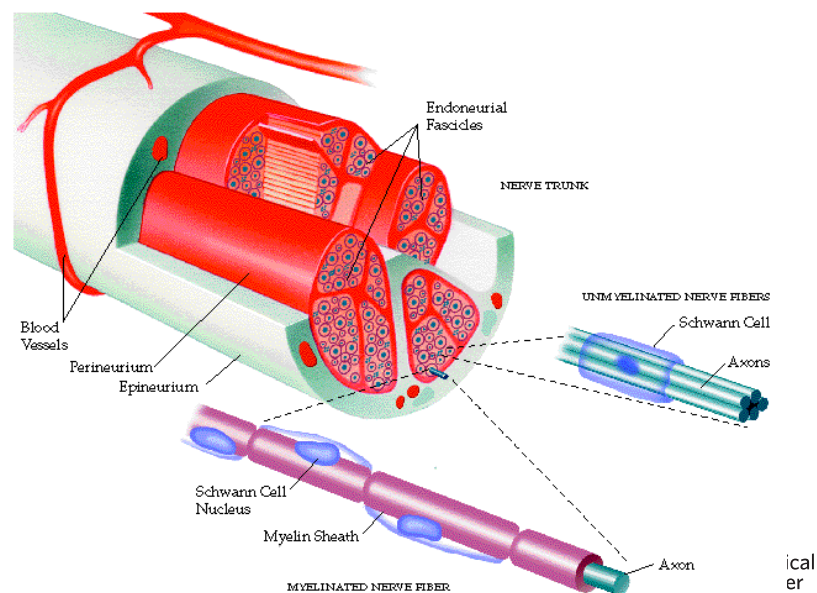
Traumatic Nerve Injuries Sunderland Classification



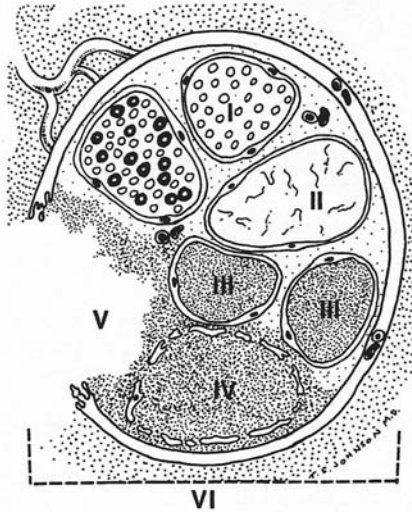
- Each axon may respond differently to the cut, stretch, or crush of the injury.
- In acute phase use needle EMG to search for a motor unit potential(s), the presence of working motor units suggests that the nerve's perineurium is not completely severed.
- Blood supply not usually a factor, vasa nervorum is a rich plexus.



Fascicle Anatomy



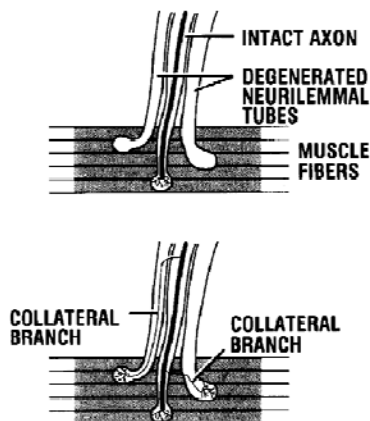
Traumatic Nerve Injuries Mixed Injury Types



- MacKinnon has suggested that mixed injuries be considered Type VI
- Injuries may require differing treatments in different fascicles
- Many injuries are mixed in character
- Cut, gouge, contuse, and stretch



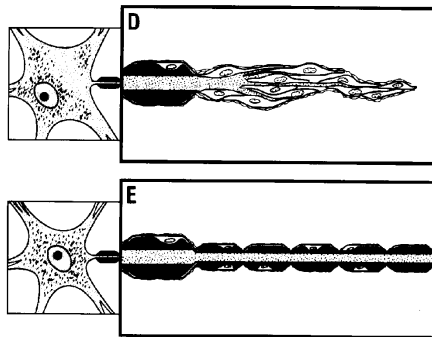
Traumatic Nerve Injuries Axon Sprouts



- Axonal sprouting can occur within a few days from survivor axons in partial injury
- Sprouts arise from Nodes of Ranvier near nerve terminal and from the terminal branch

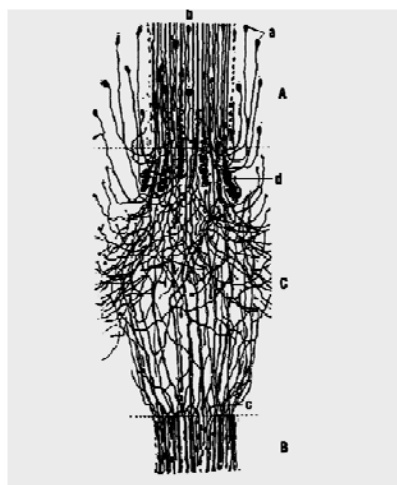


Traumatic Nerve Injuries Nerve regeneration



- Axon regeneration begins within 36 hr
- 1-3 mm/d axon growth for most nerves, faster proximal
- Follow endoneurial tubes, if possible

Traumatic Nerve Injuries Regeneration



- Sprouting occurs randomly during recovery and growth
- Axons within neural tubes and Schwann cells survive
- Synkinesis can develop as axons branch and sprout into the wrong muscles.

Traumatic Nerve Injuries

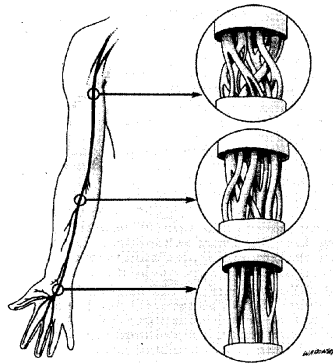


FIGURE 35-4. The internal topography of the median nerve. The degree of plexus formation that occurs between fascicles decreases in the distal portion of the extremity. (From MacKinnon SE, Dellon AL: Surgery of the Peripheral Nerve. New York: Thieme Medical Publishers, 1988.)

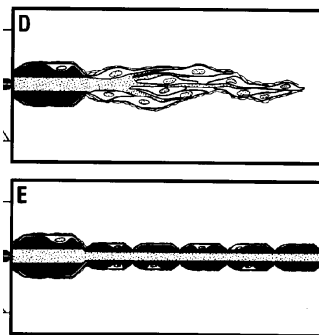
- Nerve fascicles do not travel parallel linear paths
- Complicates surgical repair when a proximal segment is missing



MacKinnon, '88



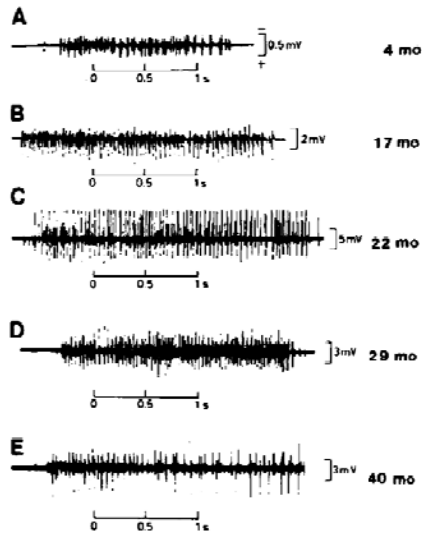
Traumatic Nerve Injuries



- Nerve conduction velocity can approach, but not reach the normal speed (60-85%).
- Axon diameter smaller (60%). Myelin thinner, internodes shorter.
- CMAP amplitude correlates with muscle mass.



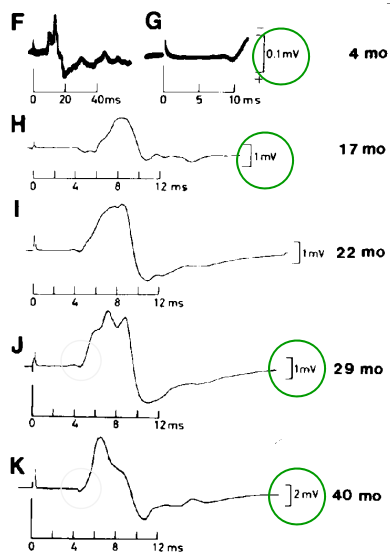
Traumatic Nerve Injuries Regeneration



- Recovery over short median nerve segment.
- Recruitment order random rather than according to “size principle.”
- Note amplitude reduction between 22 and 29 months.



Traumatic Nerve Injuries Regeneration

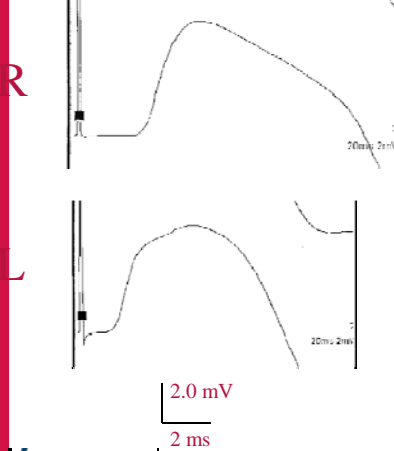


- Progressive improvement in amplitude and latency of CMAP
 - Note gain adjustments
- Loss of clear “motor point” zone, hard to get good “take-off”
 - Sprouting leads to new NMJ locations



Traumatic Nerve Injuries Nerve Repair-Anastomosis

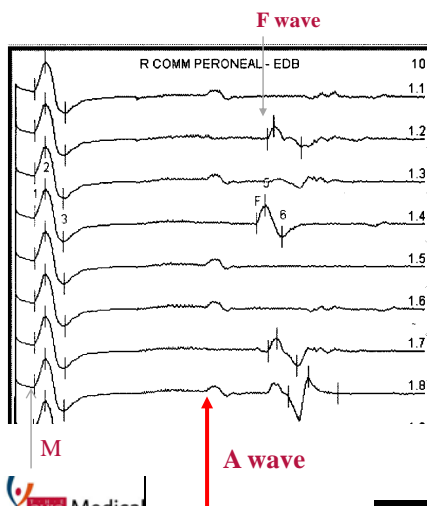
Record Trapezius; Stim Accessory



- Post-operative motor nerve response 3 years post CN XI repair (R).
- Surgical mishap
- Latency delayed and duration increased (temporal dispersion), with peak amplitude normal.



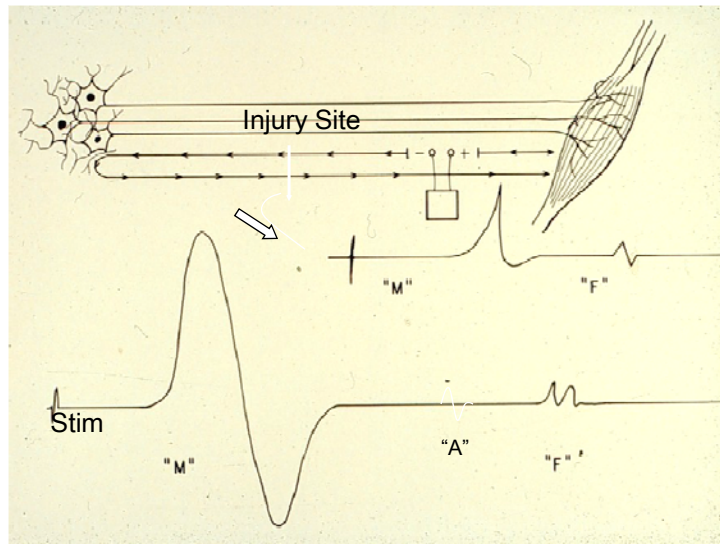
Traumatic Nerve Injuries Nerve repair



- When recording F-waves, "A" waves can appear.
- The A-wave represents aberrant conduction at the injury site
 - Ephaptic
 - axon sprout



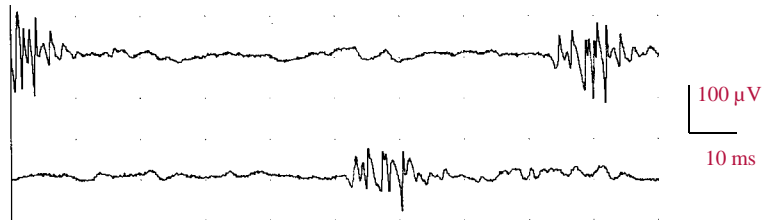
Axon (A) Wave



Note: A wave can appear before or after the F wave



Traumatic Nerve Injuries This is an exciting finding!



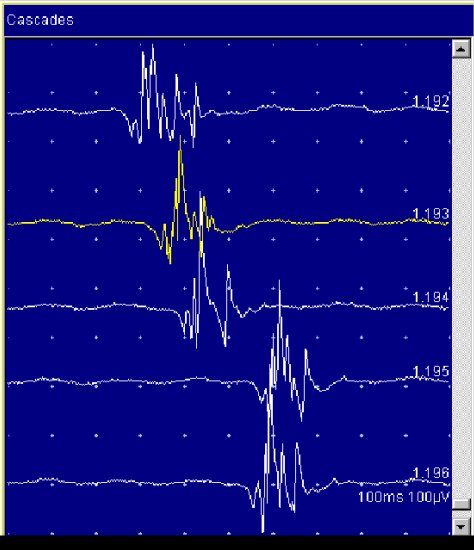
- First regenerated axons produce nascent potentials;
 - **Small, polyphasic units which fatigue easily.**
 - **Can be confused with fibs since only 1 or 2 muscle fibers may be active.**
 - **Muscle movement may not visible.**
 - **Muscle reinnervation, finally**





- Slow firing rate
- Polyphasic
- Unstable
- Fatigues easily
 - Allow rest during needle study


Nascent Potential

1st sign of axon regrowth





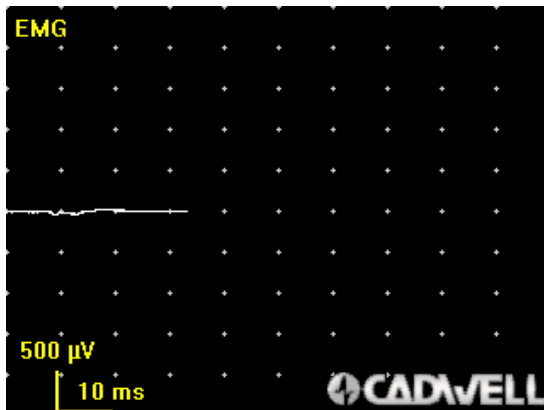
Traumatic Nerve Injuries Regeneration



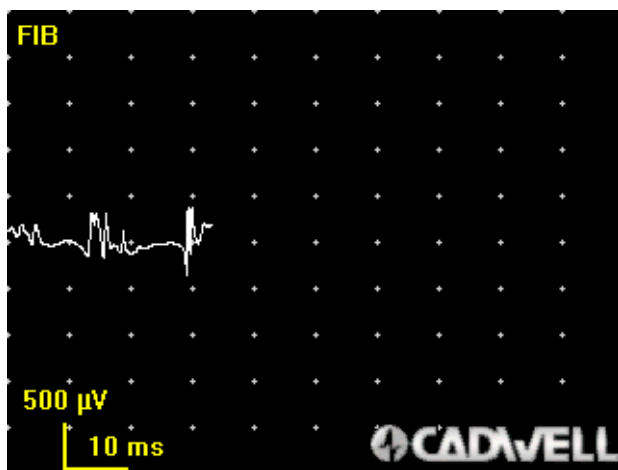
- Regeneration progresses which produces polyphasic MUPs of larger size, and continued abnormal recruitment.
- Unstable motor unit potentials (immature NMJ's) with variation in subsequent appearances.

Polyphasic and Unstable MUP



Larger Amplitude, Polyphasic MUAPs with Shorter Duration



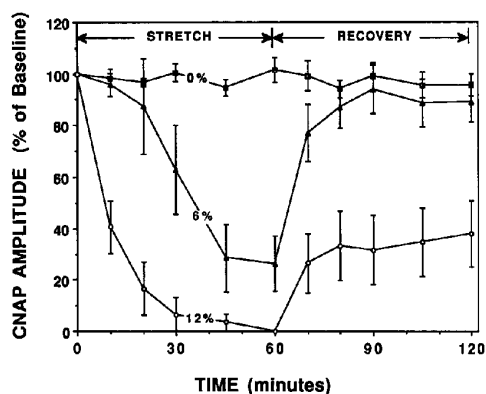
Traumatic Nerve Injuries Regeneration



- Complete regeneration leaves continued abnormal recruitment, decreased number of MUPs.
- Large amplitude MUPs @ 30-40 Hz.
- Fiber density abnormal on SFEMG, although jitter (stability) may return to normal.



Traumatic Nerve Injuries Stretch Injury

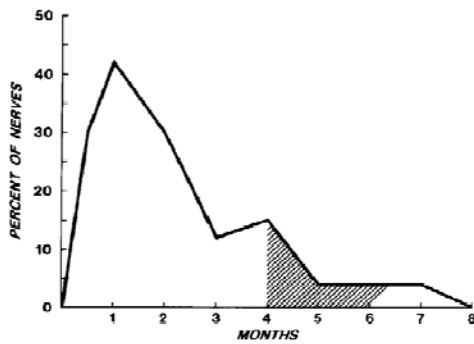


- Stretch injury to nerve, relation of strain to injury
- With strain (lengthening) of 6%, there is transient nerve dysfunction
- With strain (lengthening) of 12%, there is persisting injury to most axons

Figure 3-5. The amplitude of the compound nerve action potential (CNAP), expressed as a percentage of the baseline values prior to nerve stretch. Significant decreases with 6% and 12% strains are seen. Upon release of the strains, the 6% group shows good recovery, while the 12% group shows incomplete recovery.



Traumatic Nerve Injuries Spontaneous Recovery



- How long to wait!?
 - When no MUP or CMAP seen!
- Spontaneous healing of nerve occurs in 4-6 months (80-90%)
- Between 4-6 mon is time to consider surgical repair.

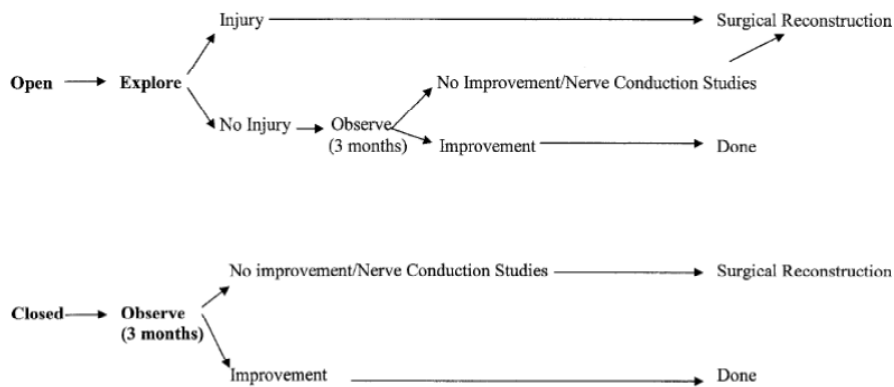


FIG. 1. Radial nerve palsy algorithm.

- Recommends surgery for nerve repair if EMG does not show function at three months
- Active hand therapy during waiting/observation
 - Lowe JB, Sen SK, and Mackinnon SE, Plast Reconstr Surg 2002;110:1099



Surgery Recommendations

- Surgery immediate for sharp and vascular;
- Or Wait:
- 2-3 weeks for blunt/dull penetrating (✓EMG);
- 3 months for GSW;
- 4 months for closed injury
- Outcome 3yr grade 3 recovery or better (prox=4/5, distal=3/5)
- 81% neurolysis
- 61% graft
- 40% neurotization
 - Transfer 2nd nerve



Dubuisson AS, *Neurosurgery* 2002;51:673



Poor outcomes associated with delayed surgery (when surgery is needed)

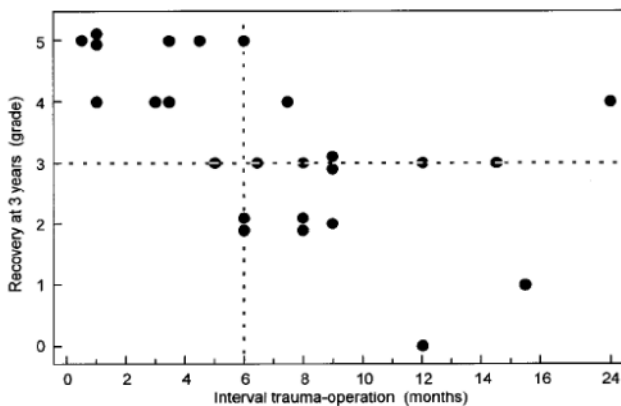


FIGURE 3. Scatterplot of postoperative outcomes at 3-year follow-up in 25 patients with C5–C6 or C5–C7 stretch injuries that were repaired by nerve grafting, according to timing of surgery.

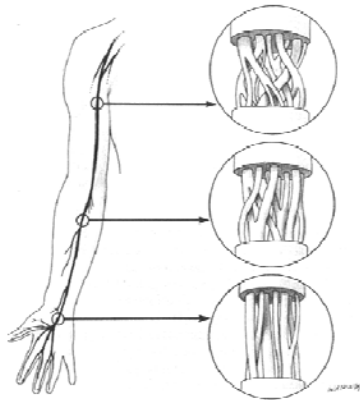


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Traumatic Nerve Injuries

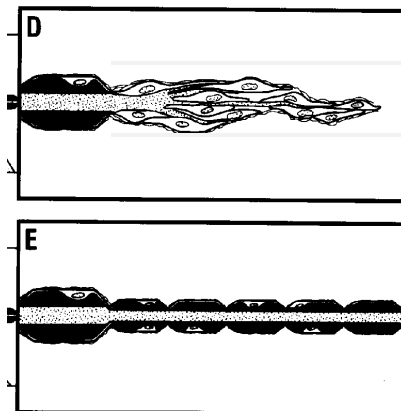
Nerve repair



- Post-operative recovery after nerve repair improves with:
 - Younger age
 - Shorter distance to muscle
 - 90% recovery in young, distal injury
- Sensation will partially recover before strength
 - CNS amplifies input

Traumatic Nerve Injuries

Graft for repair



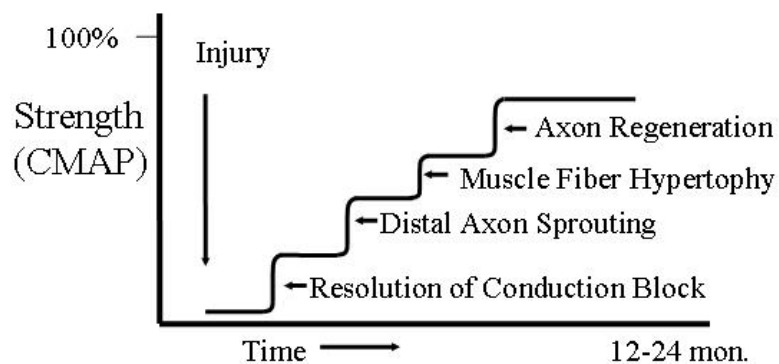
- Nerve conduction velocity 50-75%, at best
- Vascular supply is from nerve anastomosis
- Auto grafts preferred, but allografts (transplant) can be used since graft is temporary conduit for axon regrowth, and is replaced
 - Immunosuppression is temporary

Traumatic Nerve Injuries EMG Phases of Recovery

- After Injury (immediate)
 - ↓ # Motor Unit Potentials (MUP)
- After Wallerian Degeneration
 - ↓ Amp CMAP, NAP (sensory or mixed)
 - + Abundant Fibs, PSW
- After Axon Sprouting
 - Complex Polyphasic MUP, Unstable
 - ↑ Size CMAP
 - ↑ Size MUP, Gradually
- After Axon Regeneration
 - ↑ Number MUPs, Nascent Potentials
- Muscle Hypertrophy-all working MUPs
 - Additional size MUPs
- Continued Remodeling of mature MUP
 - MUPs approach normal size



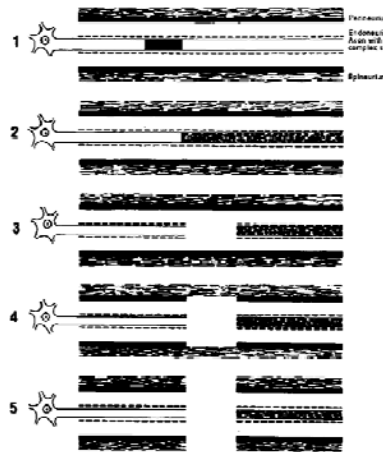
Traumatic Nerve Injuries Clinical Phases of Recovery- Strength



Modified From Robinson LR; Muscle Nerve 2000



Prognosis According to Classification of Injury



- 1. Neurapraxia-complete recovery days to 3 months
- 2. Axonotmesis-growth 1 mm/d, near-complete
- 3. Endoneurial injury-partial recovery, 1 mm/d
- 4. Loss of Perineurium-does not recover
- 5. Neurotmesis-needs surgery, then like 3
- 6. Neuroma in Continuity (Mixed recovery pattern)
- Note: Prognosis worsens for proximal injury

Prognosis According to Motor Nerve Response (CMAP)

- At 10 to 15 days post-injury, Compare with contralateral nerve (or reference value)
- If loss is <50%, Prognosis is Excellent
- If loss is 50-80%, Prognosis is fair to good (more than 20% of axons survive)
- If loss is >90%, Prognosis is poor



Prognosis According to Motor Nerve Response (CMAP)

- At 10 to 15 days post-injury, Compare with contralateral nerve (or reference value)
- If loss is <50%, Prognosis is Excellent
 - Sprouting will reinnervate
- If loss is 50-80%, Prognosis is fair to good (more than 20% of axons survive)
 - Neural tube still viable for new axons
- If loss is >90%, Prognosis is poor, especially if proximal.
 - Intraneural adhesions blocking recovery



Neuropathic Weakness Rehab Treatment

- 1. "Overuse can damage muscles, sometimes to the point of no recovery"
 - (Herbison GJ; APMR 1983)
- Series of experiments on rats with sciatic nerve injuries; overuse by tenotomy of synergist

Not-so-Therapeutic Exercise

- Overload work of muscles produced by excision of agonist.
 - i.e. Tib anterior exercised after removal of Extensor Dig.
1. Reduced strength with tetanic twitch by stimulation.
 2. Slowed twitch response



Exercise after Nerve Injury

- Edx showed recovery of CMAP and decreasing fibs at 3 weeks post-injury
- Strenuous exercise begun at 2 weeks retarded recovery of muscle size and fiber protein
- Strenuous exercise begun after 3 weeks recovery results in normal muscle hypertrophy
- **➡** Exert muscle only after fibs are gone

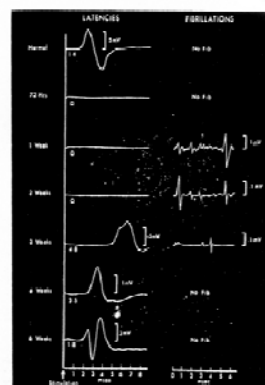


Fig. 1. Changes in nerve-stimulated tetanic stimulation of gastrocnemius at 0, 2, 4, and 6 weeks post-injury. Note the loss of conduction at 2 weeks, the appearance of fibrillations in the distribution phase, the reappearance of the tetanic and delayed tetanic to gastrocnemius as he recovers in the recovery phase after 3 weeks. The bars indicate the gate scale in milliseconds for both fibrillations and tetanic.



Herbison GJ; Exp Neurol 1973



Exercise in Rehab After Nerve Injury

1. Maintain motion/flexibility

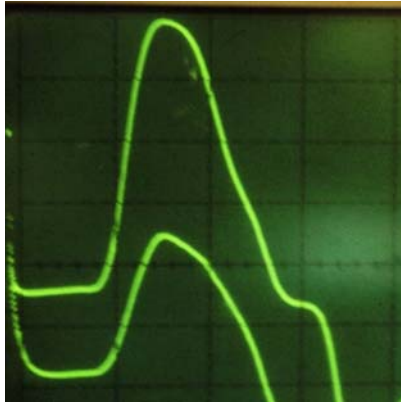
2. Avoid strenuous progressive resistive exercises

- (no 10RM-DeLorme exercise)
- No exercise to fatigue
- Avoid eccentric exercise
- Adapt to reduce frequency of eccentric work in ADLs

STRENGTHENING EXERCISE Sub-maximal

**Maintenance of strength
is usually achieved with
a regular program of
20% MVC of muscle
contraction**

The KEY word



- AMPLITUDE
- AMPLITUDE
- AMPLITUDE
- AMPLITUDE
- AMPLITUDE

References

- Davis LE, Neurology 2004;63:1070
- Dawson, Hallett & Wilbourn, *Entrapment Neuropathies* (text)
- Dubuisson AS, Neurosurgery 2002;51:673
- *Johnson's Practical EMG*, 2007 (text)
- Maggi SP, Clin Plastic Surg 2003;30:109
- Robinson LR, Muscle Nerve 2000;23:863


The Chief Wheelie!!



Go to Youtube:
"Johnson Wheelie"
For Instruction

Dr. Johnson

More Questions?



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Dodd Rehabilitation
480 Medical Center Drive

Questions?

- William S. Pease, M.D.
- Ernest W. Johnson Professor of PM&R
- William.pease@osumc.edu



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