<table>
<thead>
<tr>
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<th>NEUROPATHY</th>
<th>MYOPATHY</th>
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<tbody>
<tr>
<td>Weakness</td>
<td>distal</td>
<td>proximal</td>
</tr>
<tr>
<td>Sensory dysfunction</td>
<td>+</td>
<td>0</td>
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<tr>
<td>Loss of reflexes</td>
<td>early</td>
<td>late</td>
</tr>
<tr>
<td>Serum enzymes</td>
<td>+/-</td>
<td>+++</td>
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<tr>
<td>CSF protein</td>
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<tr>
<td>Electromyography</td>
<td>neurogenic</td>
<td>myopathic</td>
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CLASSIFICATION OF PERIPHERAL NERVE DISEASES

Myelinopathy
   Acute inflammatory polyneuropathy (Guillain-Barré syndrome or GBS)
   Chronic inflammatory demyelinating polyneuropathy (CIDP)
   Charcot-Marie-Tooth, type 1 (CMT-1)

Axonopathy
   Wallerian degeneration (trauma, vasculitis etc.)
   Distal axonopathies (dying back neuropathies)

Neuronopathy
   Amyotrophic lateral sclerosis (ALS)
CLINICAL ROLE OF NERVE BIOPSY IS VERY LIMITED

• Identify the cause of a neuropathy (vasculitis, amyloidosis).

• Nerve conduction studies are more useful than nerve biopsy for distinguishing between a demyelinating neuropathy and an axonal disorder.
PATHOLOGICAL ANALYSIS OF SURAL NERVE BIOPSY

- ROUTINE HISTOLOGY
- SEMITHIN PLASTIC SECTIONS
- TEASED MYELINATED FIBERS
- ELECTRON MICROSCOPY
SURAL NERVE, SEMITHIN PLASTIC SECTION (TOLUIDINE BLUE)
TEASED MYELINATED FIBER: NORMAL
SEQUENCE OF SEGMENTAL DEMYELINATION & REMYELINATION

Prox.  Dist.

Conduction block of action potentials
Conduction slowing
NERVE STIMULATION EVOCKES ACTION POTENTIAL IN HAND MUSCLE


NORMAL COMPOUND MUSCLE ACTION POTENTIAL

REDUCED AMPLITUDE OF CMAP
TEASED MYELINATED FIBER: SEGMENTAL REMYELINATION
SAME TEASED FIBER AT HIGHER MAGNIFICATION
SEQUENCE OF SEGMENTAL AXONAL DEGENERATION & REGENERATION

Proximal

Distal
TEASED MYELINATED FIBER: AXONAL DEGENERATION
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ACUTE INFLAMMATORY POLYNEUROPATHY
(GUILLAIN-BARRE SYNDROME OR GBS)

• Rapidly progressive neuropathy, chiefly motor, reaching maximum weakness usually within 1 to 2 weeks.

• Severe respiratory weakness is a major danger and may require treatment in an intensive care unit.

• An acute infectious illness precedes weakness in two thirds, consisting of influenza-like symptoms or diarrhea. The respiratory disorder is linked to infection by viruses whereas diarrhea is often caused by *Campylobacter jejuni*.

• Recovery takes weeks or months. Permanent handicap occurs in 15%-20% of patients.
GBS: DIAGNOSIS & TREATMENT

- Electrophysiology: early block of conduction of action potentials along motor nerves. Slowing of conduction velocity develops later as segmental remyelination appears.

- Electrodiagnostic studies often show evidence of co-existing axonal degeneration, usually of mild degree.

- Cerebrospinal fluid typically has mildly elevated protein and no cells.

- Sural nerve biopsy does not have a role in diagnosis but has provided information about etiology and pathogenesis.

- Plasmapheresis or intravenous gamma globulin speeds recovery.
PATHOLOGY OF GUILLAIN-BARRÉ SYNDROME

- Immune complexes (C3, IgG, IgM) are detectable on the surface of myelin sheaths in the early stage.

- Sparse T cells, chiefly CD4 subset, infiltrate endoneurium.

- Monocytes and macrophages appear to attack myelin sheaths.

- Myelinated fibers show segmental demyelination during the first few days. Segmental remyelination occurs subsequently.

- The lesions have a perivenular distribution and tend to affect the DRG, nerve roots and adjacent nerves where blood nerve barrier is normally more permeable than elsewhere.
GBS, C3 COMPONENT ON MYELIN SHEATHS
EVIDENCE FOR AUTOIMMUNE ETIOLOGY IN GUILLAIN-BARRE SYNDROME

• Demyelinating neuropathy can be induced in experimental animals by immunization with myelin, purified myelin protein or galactocerebroside.

• Antibody titers to nerve myelin in patients correlate with disease activity.

• The antibodies recognize specific glycolipids or glycoproteins of peripheral myelin in a minority of patients.

• Immune complexes are found at surface of myelin sheaths.

• Plasmapheresis or intravenous gamma globulin speeds recovery when treatment is started early.
AXONAL VARIANT OF GUILLAIN-BARRE SYNDROME

- Clinical syndrome resembles Guillain-Barre syndrome, but is often purely motor.
- It is common in Asia and other countries but accounts for only 5% of patients in the US or Europe.
AXONAL VARIANT OF GBS, Possible molecular mimicry

- The patients often have elevated serum autoantibodies that recognize the terminal oligosaccharide of GM1 & GD1a ganglioside.

- The chemical structure of lipopolysaccharide of *C. jejuni* has the same oligosaccharide chain present in GD1a and GM1.

- This suggests that the immune response to *C. jejuni* induces antibodies that crossreact to a self-antigen of the axolemma. This axonal variant of GBS.
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CHRONIC INFLAMMATORY DEMYELINATING POLYNEUROPATHY (CIDP)

- Chronic progressive or relapsing neuropathy, motor > sensory.
- An antecedent infectious illness is uncommon.
- Electrophysiology: conduction block and slowing of velocity.
- Pathology: segmental demyelination and remyelination, onion bulbs, fibrosis and little or no lymphocytic infiltration of tissue.
- Probably an autoimmune disorder of myelin but pathogenesis is not well understood.
- Patients respond to plasmapheresis, intravenous gamma globulin or corticosteroid treatment.
ONION BULB
CIDP WITH ONION BULBS
CLASSIFICATION OF PERIPHERAL NERVE DISEASES

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Neuronopathy
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CHARCOT-MARIE-TOOTH, TYPE I

- Slowly progressive distal limb weakness begins in first decade with great variation in onset; few sensory complaints.

- Autosomal dominant, mutations commonly affect \textit{PMP22}.

- Neurological exam:
  Atrophy of distal leg muscles (stork leg appearance).
  Palpable nerve enlargement in 50%.
  Pes cavus and hammer toes is common.

- Electrophysiology: Uniform slowing of conduction velocity.
  No conduction block.

- Pathology: similar to CIDP.
Lou Gehrig
AMYOTROPHIC LATERAL SCLEROSIS (LOU GEHRIG’S DISEASE)

- Progressive weakness, muscle wasting and fasciculations; often asymmetrical in the beginning.
- Symptoms usually begin after the age of 40.
- Hyperactive tendon reflexes, clonus and Babinski signs.
- Electromyogram: Signs of denervation in muscle. Normal or slightly reduced conductions.
- Most are sporadic; about 10% are familial.
- Death occurs usually within 3 to 5 years from onset.
ALS: FASCICULATIONS & BABINSKY REFLEXES
ALS: LOWER MOTOR NEURON PATHOLOGY

• Loss of motor neurons in ventral horns and nuclei of cranial nerve V, VII, IX-XII.
• Sparing of motor nuclei of cranial nerves III, IV & VI and Onuf’s nucleus.
• Surviving motor neurons show atrophy & inclusions.
• Few chromatolytic-like nerve cells.
• Little or no evidence of axonal regeneration.
ALS: LOSS OF MOTOR NEURONS IN VENTRAL HORN
ALS, SKEIN-LIKE INCLUSIONS, UBIQUITIN
SKEIN-LIKE INCLUSIONS

- Intracytoplasmic aggregates of granules and loosely-arranged fibrils (skein-like inclusions) occur in motor neurons of spinal cord and brain stem. Rare in Betz motor cells of precentral gyrus.

- Invisible in routine histology (H&E) and are not argyrophilic.

- The inclusions are composed of TDP-43, a protein that is normally expressed in the nucleus.

- The skein-like inclusions are ubiquinated.

- Sensitivity: 90-100%; specificity: >95%.
ALS, NEUROFILAMENT PROTEIN
ALS: UPPER MOTOR NEURON PATHOLOGY

- Loss of Betz cells (upper motor neurons) in pre-central gyrus.

- Pyramidal degeneration with gradually increasing myelin pallor in a caudal direction due to loss of axons.

- The tract degeneration is marked by macrophages (removing myelin debris) and numerous activated microglia.
ALS, MYELIN PALLOR IN PYRAMIDAL TRACT, LFB-PAS
Mutations of the Cu/Zn superoxide dismutase (SOD1) cause ALS of 20% of familial cases. Expression of mutant human SOD1 in transgenic mice produces MND by a toxic or gain of function mechanism. This mouse model has yielded two major hypotheses of toxicity:

- aberrant oxidation ↔ intracellular aggregates
- glutamate toxicity, disrupted calcium homeostasis, abnormal nitration and glycation of proteins, apoptotic death
AIMS OF MUSCLE BIOPSY

- Distinguish a neurogenic disorder from a myopathy.
- Screen inherited myopathies for molecular analysis.
- Subclassify acquired myopathies.
CRYOSECTION OF SKELETAL MUSCLE, H&E
CRYOSECTIONS OF SKELETAL MUSCLE, ATPase
MODIFIED GOMORI TRICHROME

SUCCINATE DEHYDROGENASE
DIAGNOSTIC HISTOLOGICAL FEATURES
OF A NEUROGENIC DISORDER

• LARGE GROUPS OF ATROPHIC FIBERS
• FIBER TYPE GROUPING
• TARGET FIBERS
GROUPS OF ATROPHIC MYOFIBERS, H&E
FIBER TYPE GROUPING

NADH-DEHYDROGENASE

ATPase
TARGET FIBERS, NADH DEHYDROGENASE
DIAGNOSTIC HISTOLOGICAL FEATURES OF MYOPATHIES

• ABSENCE OF NEUROGENIC ABNORMALITIES
• NECROTIC MUSCLE FIBERS
• BASOPHILIC (REGENERATING) MYOFIBERS
• FIBROSIS OF THE ENDOMYSIUM
• SPECIAL PATHOLOGICAL FEATURES (INFLAMMATORY CELLS, RAGGED RED FIBERS ETC.)
REGENERATING FIBER, H&E
GOWER’S SIGN

Gowers, 1879
DUCHENNE MUSCULAR DYSTROPHY

- X-linked recessive inheritance
- Onset of weakness noticeable at 2-5 years of age.
- Progressive weakness, proximal > distal
- Hypertrophy of calves
- High serum creatine kinase activity
- Fatal in 3rd decade
DUCHENNE DYSTROPHY, LATER STAGE
DUCHENNE MUSCULAR DYSTROPHY

• Dystrophin is a 427 kD protein that binds to the inner face of the surface membrane.

• The protein has amino acid sequence similarities with alpha-actinin, an actin binding protein.

• The protein links actin to the surface membrane and the basal lamina acting through dystroglycan and merosin (alpha 2-laminin).

• Interrupting this linkage causes the surface membrane to be unstable leading to fiber injury.
INFLAMMATORY MYOPATHIES

- Polymyositis
- Inclusion body myositis
- Dermatomyositis
POLYMYOSITIS
DIAGNOSTIC FEATURES OF POLYMYOSITIS

- Subacute progressive weakness, proximal>distal. Usually adults, women more common than men.
- Elevated serum creatine kinase activity.
- Electromyogram: myopathic potentials, spontaneous activity.
- Muscle biopsy: inflammatory myopathy affecting chiefly the endomysium.
- Usually respond to glucocorticoids.
POLMYOSITIS, IMMUNOPEROXIDASE, CD8
POLYMYOSITIS: PATHOLOGY

- Necrotic fibers and regenerating fibers randomly distributed throughout the muscle specimen.

- CD8 cytotoxic cells infiltrate predominantly the endomysium with invasion of rare myofibers.

- Little fibrosis or myofiber hypertrophy, consistent with a subacute disorder.
INCLUSION BODY
MYOSITIS
DIAGNOSTIC FEATURES OF IBM

• Most common inflammatory myopathy in patients over the age of 50 years and affects mostly men.

• Slowly progressive weakness, proximal and distal.

• Mildly elevated serum creatine kinase or normal.

• Electromyogram: myopathic potentials, spontaneous activity.

• Muscle biopsy: resembles polymyositis, but chronic and exhibits rimmed vacuoles and amyloid inclusions.

• Usually does not respond to glucocorticoids.
IBM, EOSINOPHILIC INCLUSION IN A RIMMED VACUOLE
ELECTRON MICROSCOPY, 15-20 nm FILAMENTS
IBM PATHOLOGY

- IBM resembles polymyositis but has hypertrophic fibers and prominent endomysial fibrosis indicating it is chronic.

- Rimmed vacuoles.

- Congophilic fibrillar inclusions, composed of abnormal (? paired-helical) filaments.

- Lymphocytic infiltration suggests an autoimmune disorder, but disorder is usually unresponsive to immunosuppression.
DERMATOMYOSITIS
DIAGNOSTIC FEATURES OF DERMATOMYOSITIS

• Subacute progressive weakness, proximal > distal. Children and adults, women more common than men.

• Characteristic rash on face, chest & extensor surfaces.

• Elevated serum creatine kinase activity.

• Electromyogram: myopathic potentials, spontaneous activity.

• Muscle biopsy: inflammatory myopathy affecting chiefly the perimysium with perifascicular atrophy.

• Usually respond to glucocorticoids or IVGG.
DERMATOMYOSITIS: LYMPHOCYTE PHENOTYPES

- CD4 T cells and B cells located chiefly in connective tissue and around vessels of perimysium.

- Inconstant and usually sparse CD8 T cells located mainly in endomysium.
DM, IMMUNE COMPLEXES (C5b-9) IN BLOOD VESSEL WALL
TUBULORETICULAR AGGREGATE IN ENDOTHELIAL CELL
DERMATOMYOSITIS: PATHOLOGY

• Perifascicular atrophy of muscle fibers, with or without necrotic fibers or regenerating fibers.

• Immune complexes of immunoglobulins and complement components in the walls of blood vessels.

• Endothelial tubuloreticular aggregates.

• Reduced number of capillaries at periphery of fascicle.

• Lymphocytes are often sparse and located in chiefly perimysium.
INFLAMMATORY MYOPATHIES: PATHOPHYSIOLOGY

- Polymyositis and inclusion body myositis (IBM) have autoaggressive CD8 lymphocytes that appear to attack myofibers and suggest an autoimmune role. However, a major question exists about the etiology and pathogenesis of IBM.

- Dermatomyositis is thought to be caused by autoantibodies, possibly targeting an antigen of the endothelium. The pathological findings suggest that myofiber injury may be caused by ischemia.
## HYPOTONIA IN INFANCY

<table>
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<tr>
<th>DISEASE</th>
<th>INHERITED</th>
<th>PROGNOSIS</th>
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<tbody>
<tr>
<td>Werdnig-Hoffmann disease</td>
<td>Autosomal recessive</td>
<td>Fatal</td>
</tr>
<tr>
<td>Central core disease proggressive</td>
<td>Autosomal dominant</td>
<td>Not progressive</td>
</tr>
<tr>
<td>Nemaline myopathy</td>
<td>Variable</td>
<td>Variable</td>
</tr>
<tr>
<td>Mitochondrial disorder</td>
<td>Maternal or autosomal</td>
<td>Variable</td>
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WERDNIG-HOFFMANN DISEASE
CENTRAL CORE DISEASE, NADH DEHYDROGENASE
MITOCHONDRIAL MYOPATHY
MUTATIONS OF mtDNA RAGGED “RED” FIBER
CYTOCHROME C OXIDASE DEFICIENT MYOFIBER
RRF, SUCCINATE DEHYDROGENASE