Chapter 21
The Nervous System

Learning Objectives (1 of 2)
• Describe normal structure and function of the brain, meninges, CSF in relation to neurologic disease
• Define muscle tone, voluntary motor activity and relate to two forms of muscle paralysis
• Explain pathogenesis, prenatal diagnosis, clinical manifestations of closure defects of the CNS
• Describe pathogenesis, clinical manifestations of hydrocephalus and relate to treatment measures
• Describe causes, manifestations, treatment of transient ischemic attack, TIA

Learning Objectives (2 of 2)
• Differentiate types of stroke as to pathogenesis, prognosis, and treatment
• Describe pathogenesis, manifestations, treatment of congenital cerebral aneurysms
• Explain pathogenesis, origin, clinical manifestations, and treatment of CNS tumors
• Explain pathogenesis, clinical manifestations, and treatment of Parkinson’s disease, meningitis, multiple sclerosis, and Guillain Barre syndrome
Nervous System

- Central nervous system, CNS
  - Brain
  - Spinal cord
- Meninges: surrounding membranes
  - Neurons (nerve cells) and neuroglia (supporting cells)
  - Sensory or afferent nerve: transmits impulses to the nervous system
  - Motor or efferent nerve: transmits impulses from brain or spinal cord to muscle
  - Transmission of a nerve impulse via neurotransmitters
    - Acetylcholine, norepinephrine, dopamine

Meninges

- Dura: firm, outer covering
- Arachnoid: middle
  - Subarachnoid space: space between arachnoid and pia contains
    - CSF (cerebrospinal fluid)
    - Strands of arachnoid connective tissue
- Pia: thin, inner membrane
  - Adheres to brain and spinal cord

Brain

- Cerebrum
- Cerebellum
- Brain stem
- Brain: four cavities called ventricles
  - Tissues of brain and spinal cord
    - Nerve cells = neurons
    - Supporting cells = neuroglia
  - Arterial blood supply
    - Large vessels enter base of skull
    - Vessels join to form arterial circle at base of brain
  - Venous blood
    - From brain into large venous sinuses in dura
    - Sinuses eventually drain into jugular veins
Development of Nervous System

- Neural plate becomes neural tube
- Forebrain forms cerebral hemispheres and diencephalon
- Midbrain and hindbrain form remainder of adult brain
- Mesoderm surrounding neural tube forms cranial cavity, vertebral bodies, and surrounding structures

Voluntary Motor Activity

- Controlled by nerve impulses originating in motor neurons of the cerebral cortex (cortical neurons)
- Muscle tone caused by reflex arcs
- Pyramidal system controls voluntary motor functions
- Extrapyramidal system regulates muscle groups concerned with automatic functions such as walking

Muscle Paralysis

- Flaccid paralysis
  - Destruction of motor neurons by disease
  - Interruption of reflex arc responsible for muscle tone
  - Muscle deprived of innervation
  - Low muscle tone
  - Peripheral nerve destruction
- Spastic paralysis
  - Reflex arc not disturbed
  - Injury to cortical neurons stops voluntary control
  - Muscle retains innervation
  - Increased muscle tone
Cerebral Injury

- Large blood vessels over surface of brain may be torn by force of injury
  - Epidural hemorrhage
  - Subdural hemorrhage
  - Subarachnoid hemorrhage

Mechanism of injury to frontal and temporal poles of brain caused by blow to back of head.

Skull x-ray illustrating large skull fracture (arrows) associated with extensive injury to underlying brain.
Neural Tube Defects

- **Anencephaly**
  - Failure of normal development of brain and cranial cavity
  - Multifactorial inheritance

- **Spina bifida**
  - Diagnosis: amniocentesis and alpha-fetoprotein levels
  - Alpha-fetoprotein leaks from fetal blood into amnionic fluid through open neural tube defect; high levels found in amnionic fluid
    - Occult
    - Meningocele
    - Meningomyelocele

Characteristic appearance of anencephalic infant

Characteristic appearance of anencephalic infant. Lateral view.
Various types of spina bifida.

Neural Tube Defects
A. Thoracic meningomyelocele covered by thin membrane
B. Large meningomyelocele associated with neurologic deficit

Hydrocephalus
- Congenital hydrocephalus
  - From congenital obstruction of aqueduct or absence of openings in roof of 4th ventricle
  - Head enlarges as ventricles dilate because cranial structures have not fused
- Acquired hydrocephalus
  - Obstruction of CSF by tumor or adhesions blocking opening in 4th ventricle
  - Ventricles dilate but head does not enlarge because cranial structures are fused
Coronal section of brain revealing marked dilation of ventricles in patient with congenital hydrocephalus.

Shunting procedures for hydrocephalus.

Stroke: Cerebrovascular Accident (1 of 5)

- Any injury to brain tissue from disturbance of blood supply to brain
- Types of stroke
  - Cerebral thrombosis: most common; thrombosis of cerebral artery narrowed by arteriosclerosis
  - Cerebral embolus: occurs less frequently; blockage of cerebral artery by fragment of blood clot from an arteriosclerotic plaque or from heart
  - Cerebral hemorrhage: most serious type of stroke; usually from rupture of a cerebral artery in person with hypertension
Stroke: Cerebrovascular Accident
(2 of 5)

• Predisposing Factors
  – Mural thrombus formed on wall of left ventricle adjacent to a healing myocardial infarction
  – Thrombus formed on rough surface of diseased mitral or aortic valve
  – Small thrombus in left atrium of person with atrial fibrillation

Stroke: Cerebrovascular Accident
(3 of 5)

• Ischemic infarct: no blood leaks into brain
• Hemorrhagic infarct: blood leaks into damaged brain tissue
• Arteriosclerosis of extracranial arteries
  – Sclerosis of a major artery from aorta that supplies brain
  – Common affected site: carotid artery in neck; arteriosclerotic plaque may narrow lumen and reduce cerebral blood flow

Stroke: Cerebrovascular Accident
(4 of 5)

• Diagnosis
  – Cerebral angiogram
  – Carotid endarterectomy
  – Less invasive methods: similar to balloon angioplasty and stent insertion procedures used to treat coronary artery plaques
Stroke: Cerebrovascular Accident (5 of 5)

- CT scan: can distinguish a cerebral infarct from cerebral hemorrhage
- Magnetic resonance imaging (MRI): provides similar information and is equally effective

Infarct, right cerebral hemisphere from thrombosis of middle cerebral artery

Effects of atherosclerosis of carotid artery

A. Narrowing of lumen
B. Thrombus formation
C. Thrombus dislodged & forms emboli
D. Complete occlusion of artery by thrombus
Carotid endarterectomy
A. Resected atherosclerotic plaque follows contour of common carotid artery and branches
B. Opened endarterectomy specimen

Coronal section of brain illustrating large cerebral hemorrhage that has compressed and displaced the cerebral ventricles.

A computed tomographic (CT) scan of a patient with cerebral hemorrhage (arrow), which appears white because blood is denser than brain tissue.
Transient Ischemic Attack, TIA

- Brief episodes of neurologic dysfunction
  - From embolization of material from plaque in carotid artery
  - One-third of patients eventually suffer major stroke
- Treatment: endarterectomy or medical therapy

Cerebral Aneurysm

- Congenital aneurysm of circle of Willis
  - Congenital weakness in arterial wall allows lining to protrude
  - Weakness is congenital but aneurysm develops in adult life
  - Rupture causes subarachnoid hemorrhage
  - Hypertension predisposes
  - Treatment: aneurysm occluded surgically
- Arteriosclerotic aneurysm
  - Cerebral artery dilates and compresses adjacent tissue
  - Rupture uncommon

Dissection of vessels from the brain of a person with large congenital cerebral aneurysm.
A cerebral aneurysm (arrow) demonstrated by an angiogram.

Undersurface of brain, illustrating subarachnoid hemorrhage secondary to ruptured cerebral aneurysm.

Infections

• Three types
  – Bacterial
  – Fungal
  – Viral
• Meningitis: infection affecting meninges
• Encephalitis: infection of brain tissue
• Meningoencephalitis: affects both meninges and brain tissue
Meningitis from Bacteria and Fungi

- Meningococcus (*Neisseria meningitidis*)
- Pneumococcus (*Streptococcus pneumoniae*)
- Hemophilus influenzae

Bacterial meningitis, illustrating purulent exudate in the meninges

Viral Infections That Affect the CNS (1 of 2)

- Measles
- Mumps
- Herpes simplex virus
- Intestinal and respiratory viruses
- Cytomegalovirus
- Poliomyelitis virus
- Arborviruses
Viral Infections That Affect the CNS (2 of 2)

- Arboviruses: responsible for cases of meningitis and encephalitis
  - Viruses infect birds, animals, humans; transmitted by mosquitoes
- Types of encephalitis
  - Western equine encephalitis
  - Eastern equine encephalitis
  - St. Louis encephalitis
  - California encephalitis
  - West Nile virus: “foreign” virus from Africa, first case identified in 1999 in New York City area

Creutzfeldt-Jakob Disease

- Caused by small protein particle produced as a result of gene mutation
  - Normal form of protein: “good prion” designated as PrPc
  - Abnormal form: “bad prion” designated as PrPsc
- Mad cow disease
  - Prion disease affecting cows
  - Cows become infected from animal feed mixed with protein-rich tissue from sheep infected with scrapie
  - Eating infected beef causes variant Creutzfeldt-Jakob disease in humans

A photomicrograph of cerebral tissue from patient with Creutzfeldt-Jakob disease.
Alzheimer Disease

- Characteristics
  - Progressive mental deterioration
  - Emotional disturbances
- Anatomic and biochemical features
  - Neurofibrillary tangles: thickening of neurofilaments
  - Neurotic plaques: clusters of thick, broken neurofilaments
  - Biochemical abnormalities and brain enzyme deficiencies: acetylcholine and acetylcholine synthesizing enzyme
- No specific treatment; some drugs may temporarily improve cerebral function

Multiple Sclerosis

- Probably an autoimmune disease in generally predisposed individual
- Random foci of demyelination followed by glial scarring
- Neurologic symptoms depend on location of plaques
- Probably initiated by a viral infection in a genetically predisposed person
- Manifestations
  - Activated T lymphocytes, monocytes target myelin proteins, destroy myelin
- Treatment
  - MRI demonstrates plaques in CNS
Coronal section of brain illustrating areas of gliarial scarring (arrows) adjacent to ventricle in multiple sclerosis.

Multiple sclerosis demonstrated by MRI.

**Parkinson Disease**
- Most cases unknown etiology
- Some develop subsequent to viral infection of nervous system or toxic drugs
- Manifestations
  - Progressive loss of neurons in substantia nigra of midbrain
  - Rigidity of voluntary muscles
  - Tremors of fingers and extremities
  - Decreased dopamine in CNS
- Treatment: relieved by L-dopa
  - Embryonic stem cells may be key to successful treatment; possible to induce stem cells to differentiate into dopamine-producing neurons to treat disease
Huntington Disease

- Progressive hereditary autosomal dominant disease
- Abnormal gene contains too many CAG triplet repeats
- Greater number of repeats, the earlier the onset
- Uncommon but well-known hereditary disease
- Manifestations
  - Progressive mental deterioration; abnormal jerky and writhing movements
  - First manifestations occur between age 30 to 50
  - Progresses and usually fatal within 15 to 20 years
  - No way to arrest progression of disease
  - Drugs may help control some of its manifestations

Degenerative Disease of Motor Neurons

- Affects both upper and lower motor neurons
- From degeneration of neurons
- Causes: weakness, paralysis, respiratory problems
- No specific treatment
- Amyotrophic lateral sclerosis, ALS
  - Affects upper and lower motor neurons
  - Flaccid paralysis of muscles
  - Respiratory problems

Tumors of Peripheral Nerves

- Usually solitary; from Schwann cells
- Neuromas of cranial nerves: usually involves acoustic nerve; difficult to remove surgically
- Multiple nerve tumors occur in multiple neurofibromatosis
  - Transmitted as Mendelian dominant trait
  - Disfiguring skin nodules, thickened patches of skin, focal hyperpigmentation of skin
  - Sarcoma arises from preexisting tumors in 10-15% of cases
Multiple skin tumors in a patient with multiple neurofibromatosis (von Recklinghausen’s disease)

Brain Tumors

- Metastatic tumors more common than primary tumors
- Primary tumors
  - Glioma: mostly poor prognosis with deep location in brain; surgery, radiation, chemotherapy; includes ependymoma and medulloblastoma
  - Astrocytoma
  - Glioblastoma multiforme
  - Oligodendroglioma
  - Lymphoma
  - Meningioma

Spinal Cord Tumors

- Same types of tumors that arise in brain
- Tumors in spinal vertebrae may extend from vertebrae to compress or invade spinal cord
  - Bone metastasis
  - Multiple myeloma
Peripheral Nerve Disorders

• Peripheral nerve injury
  – Traumatic injury: lacerations, fractures, crush injury
  – Nerve entrapment neuropathy
    • External compression by fibrous band
    • Median nerve commonly involved
    • May require surgical release if unresponsive to conservative treatment
• Polyneuritis (Peripheral neuritis)
  – Sensory and motor dysfunction in “glove and stocking” distribution
  – Proximal sensation and motor function preserved
  – From systemic disease, toxins, alcoholism
  – Treat underlying cause

HIV: Neurologic Manifestations

• Nervous system infections directly caused by AIDS virus
  – Acute viral meningitis
  – AIDS encephalopathy: chronic and progressive
  – Polyneuritis
• Nervous system infections caused by opportunistic pathogens
• Manifestations depend on location and extent of damage
  – Herpes
  – Cytomegalovirus
  – Cryptococcus neoformans
  – Toxoplasma gondii

AIDS-Related Tumors

• Primary tumor metastasizing to nervous system
  – Kaposi’s sarcoma
  – Lymphoma
  – Other malignant tumors
• Primary lymphoma of brain may occur
• Tumors respond poorly to treatment
Discussion

• What are some of the possible effects of a severe blow to the head?
• What are the common causes of hydrocephalus? How does a brain tumor cause hydrocephalus?
• What is a neural tube defect? How can it be recognized before birth?
• Compare Creutzfeldt–Jakob disease and Alzheimer disease.