A Review of Functional Neuroanatomy

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Presentation Outline

• Directionality and Orientation
• CNS Basics
• Brain Divisions
• Cortical Divisions
• CSF and Ventricular System
• Vasculature and Cerebral Blood Flow

Objectives

• Participants will readily identify the major cortical and subcortical structures within the central nervous system.
• Participants will be able to discuss the functions of specific neuroanatomical structures.
• Participants will be able to effectively describe primary pediatric neurological disorders along with the neuroanatomical correlates and behavioral symptomatology.
Presentation Outline

- Directionality and Orientation
- CNS Basics
- Brain Divisions
- Cortical Divisions
- CSF and Ventricular System
- Vasculature and Cerebral Blood Flow

Directional Terms: General

<table>
<thead>
<tr>
<th>Term</th>
<th>Description</th>
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<tbody>
<tr>
<td>Ventral</td>
<td>toward the belly/front</td>
</tr>
<tr>
<td>Lateral</td>
<td>toward the side</td>
</tr>
<tr>
<td>Anterior</td>
<td>toward the front</td>
</tr>
<tr>
<td>Rostral</td>
<td>toward the nose</td>
</tr>
<tr>
<td>Superior</td>
<td>above</td>
</tr>
<tr>
<td>Proximal</td>
<td>located close by</td>
</tr>
<tr>
<td>Ipsilateral</td>
<td>on the same side</td>
</tr>
<tr>
<td>Dorsal</td>
<td>toward the top/back</td>
</tr>
<tr>
<td>Medial</td>
<td>toward the middle</td>
</tr>
<tr>
<td>Posterior</td>
<td>toward the back</td>
</tr>
<tr>
<td>Caudal</td>
<td>toward the tail</td>
</tr>
<tr>
<td>Inferior</td>
<td>below</td>
</tr>
<tr>
<td>Distal</td>
<td>located more distant</td>
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<tr>
<td>Contralateral</td>
<td>on the opposite side</td>
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Directional Terms: Orientation Specific

<table>
<thead>
<tr>
<th>Above the Midbrain</th>
<th>Below the Midbrain</th>
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<tbody>
<tr>
<td>Anterior = Rostral</td>
<td>Anterior = Ventral</td>
</tr>
<tr>
<td>Posterior = Caudal</td>
<td>Posterior = Dorsal</td>
</tr>
<tr>
<td>Superior = Dorsal</td>
<td>Superior = Rostral</td>
</tr>
<tr>
<td>Inferior = Ventral</td>
<td>Inferior = Caudal</td>
</tr>
</tbody>
</table>
Anatomical Planes

- **Coronal**
  - Splits the front and back of the brain
  - Shows structures as seen from the front or back

- **Sagittal**
  - Splits the hemispheres
  - Shows structures as seen from the side

- **Horizontal**
  - Parallel to the floor
  - Shows structures as seen from above
Presentation Outline

- Directionality and Orientation
- **CNS Basics**
- Brain Divisions
- Cortical Divisions
- CSF and Ventricular System
- Vasculature and Cerebral Blood Flow
Central Nervous System (CNS)

- The CNS consists of:
  - Brain
  - Spinal Cord

Brain Basics

- Foramina
- Fossae
- Meninges
- Spaces
Brain Basics: Foramina

- Holes in skull allowing cranial nerves, spinal cord, and blood vessels to enter and leave cranial cavity
- Foramen magnum
  - Largest hole
  - At base of skull
  - Cervicomedullary junction

Brain Basics: Fossae

- Anterior fossa
  - Divided from middle fossa by lesser wing of the sphenoid bone
- Middle fossa
  - Divided from posterior fossa by petrous ridge of temporal bone, and sheet of meninges
- Posterior fossa
Brain Basics: Foramina and Fossae

Herniation
- Causes:
  - A lesion displaces structures so they are shifted from one compartment to another
- Congenital causes:
  - Arnold-Chiari malformation
Brain Basics: Foramina and Fossae

Herniation

• Types:
  • Transtentorial herniation
    • Herniation of medial temporal lobe
  • Central herniation
    • Downward displacement of brainstem
  • Subfalcine herniation
    • Displacement of cingulate gyrus and other nearby structures under falx cerebri

• Can cause:
  • Mass effect
  • Midline shift
  • Effacement
Mass Effect and Midline Shift

Brain Basics: Foramina and Fossae
Herniation

- Symptoms
  - Headache, vomiting, nausea, vision problems, and altered mental status
  - Uncal herniation clinical triad:
    - Blown pupil
    - Hemiplegia
    - Coma
Brain Basics: Foramina and Fossae Herniation

- Treatments
  - Neurosurgery to remove lesion
  - Decompression surgery
  - Shunt placement to control CSF flow

Brain Basics: Meninges

- Final layers within skull
- From inside to outside (PAD):
  - Pia
  - Arachnoid
  - Dura
Brain Basics: Meninges

• Pia
  • Thin layer of cells
  • Adheres closely to brain surface
  • Surrounds initial portion of each blood vessel at it enters brain surface
Brain Basics: Meninges

- Arachnoid ("spidery")
  - Adheres to inner surface of dura
  - Within arachnoid, CSF "percolates" over the surface of the brain

Brain Basics: Meninges

- Dura ("hard")
  - 2 fibrous layers
    - Periostal layer: adheres to inner surface of skull
    - Meningeal layer: fused with periostal layer except where it forms folds that descend into cranial cavity, where it occurs at the:
      - Falx cerebri
      - Tentorium cerebelli
Brain Basics: Meningitis

- Inflammation of the membranes that cover the brain and spinal cord
- Two types:
  - Bacterial: bacteria gain access to the meninges through the bloodstream, originating from infection elsewhere
  - Viral: due to other viral infections

Brain Basics: Meningitis

- Bacterial meningitis
  - Symptoms: meningeal irritation
  - CSF has high white blood cell count
  - Treatment: depends on age, antibiotics initiated quickly
Brain Basics: Meningitis

- Viral meningitis
  - Less intense and rapid than bacterial meningitis
  - Symptoms: meningeal irritation
  - Diagnosis: elevated white blood cell count, mildly elevated protein, normal glucose, EEG – periodic sharp waves over temporal lobes

Brain Basics: Meningitis

- Viral meningitis
  - Recovery occurs spontaneously in 1-2 weeks
  - Different than viral encephalitis
  - Different than meningoencephalitis
Brain Basics: Spaces

- Potential spaces formed by meninges
- Blood vessels within these spaces can cause hemorrhage
- Three types:
  - Epidural space
  - Subdural space
  - Subarachnoid space

Brain Basics: Spaces

- Epidural space
  - Between inner surface of skull and dura
  - Contains middle meningeal artery
    - Branch of the external carotid artery
    - Supplies the dura
    - Enters the skull through the foramen spinosum
Brain Basics: Spaces

- **Subdural space**
  - Between inner layer of dura and arachnoid
  - Bridging veins
    - Drain cerebral hemispheres
    - Pass through on the way to dural venous sinuses
- **Dural venous sinuses**
  - Lie enclosed within 2 layers of dura
  - Drain blood via the sigmoid sinuses to the internal jugular veins

Brain Basics: Spaces

- **Subarachnoid space**
  - Filled with CSF
  - Major arteries travel within and send smaller branches inward
Spinal Cord Basics

- Part of the CNS found within the spinal column
- Communicates with the sense organs and muscles below the level of the head
- Injuries
  - Crush or sever the spinal cord and the brain loses motor control over parts of the body at and below the injured area

Spinal Cord Basics

- Bell-Magendie Law:
  - The entering (afferent) dorsal roots carry sensory information to the brain
    - Dorsal root ganglia
  - The exiting (efferent) ventral roots carry motor information to the muscles and glands
Spinal Cord Basics

• The spinal cord is comprised of:
  • Gray matter
  • White matter
  • Each segment sends sensory information to the brain and receives motor commands
Spinal Cord Basics: Spina Bifida

- Lower neural tube closure defects
- Types
  - Spina bifida occulta
  - Spina bifida cystica
Spina Bifida Occulta

- Asymptomatic spinal lesion discovered incidentally
- Abnormal fusion of spinal lumbar vertebra
- Often asymptomatic
- No documented cognitive deficits

Spina Bifida Cystica

- Spinal defect that includes a cystic-like sac, which may or may not contain the spinal cord
- Two types:
  - Meningocele
  - Myelomeningocele or meningomyelocele
Spina Bifida Cystica: Meningocele

- Meninges and skin protrude through lumbosacral spine defect to form CSF-filled bulge
- No protrusion of spinal cord
- May cause:
  - Gait impairment
  - Kidney and bladder problems
  - Loss of tissue barriers that protect CNS

Spina Bifida Cystica: Myelomeningocele/ Meningomyelocele

- Much more common
- Tangle of rudimentary spinal cord, lumbar and sacral nerve roots, and meninges protruding into sac
- Most all are MR and paraplegic
- Causes:
  - Autosomal recessive genetic abnormality
  - Also implicated are radiation, folic acid deficiency, toxins, and AEDs
Spina Bifida Cystica

Presentation Outline

• Directionality and Orientation
• CNS Basics
• **Brain Divisions**
  • Cortical Divisions
  • CSF and Ventricular System
  • Vasculature and Cerebral Blood Flow
Brain Divisions

• The brain can be divided into three major divisions:
  1. Hindbrain (Rhombencephalon)
    • Metencephalon
    • Myelencephalon
  2. Midbrain (Mesencephalon)
  3. Forebrain (Prosencephalon)
    • Diencephalon
    • Telencephalon

Hindbrain

• Consists of the:
  • Medulla
  • Pons
  • Cerebellum
• Located at the posterior portion of the brain
• Not the same as the brainstem
Hindbrain: Medulla

- Just above the spinal cord
- Could be regarded as an enlarged extension of the spinal cord
- Controls vital reflexes through cranial nerves

Hindbrain: Medulla

- Houses the direct voluntary motor pathway from the cortex to the spinal cord
- Cranial nerves
  - Allows the medulla to control sensations from the head, muscle movements in the head, and many parasympathetic outputs to the organs
Hindbrain: Pons

- Area where many axons cross from one side of the brain to the other
- Works in conjunction to increase arousal and readiness of other parts of the brain
- Along with the medulla, contains the reticular formation and raphe system
Hindbrain

• Reticular formation
  • Descending portion is one of several areas that controls motor areas of the spinal cord
  • Ascending portion sends output to the cerebral cortex increasing arousal and attention

• Raphe system
  • Sends axons to much of the forebrain
  • Increases or decreases the brain’s readiness to respond

Hindbrain: Cerebellum

• A structure located in the hindbrain with many deep folds
• Helps regulate motor movement, balance, and coordination
• Also important for shifting attention between auditory and visual stimuli
• Damage impairs rhythm/timing and ability to shift attention between auditory and visual stimuli
Midbrain

• The midbrain consists of:
  • Tectum
    • Superior colliculus and inferior colliculus
  • Tegmentum
  • Substantia nigra
• Lies in the middle of the brain surrounded by the forebrain

Midbrain: Tectum

• “Roof” of the midbrain
• Superior and inferior colliculi
  • Swellings on each side of the tectum
  • Important routes for sensory information
    • Superior: vision
    • Inferior: audition
Midbrain: Tegmentum

• “Covering, carpet”
• Intermediate level of the midbrain
• Includes
  • Nuclei for third and fourth cranial nerves (eye movements)
  • Parts of reticular formation
  • Extensions of the pathways between the forebrain and the spinal cord or hindbrain

Midbrain

• Substantia nigra
  • Lies dorsal to the cerebral peduncles
  • Gives rise to the dopamine-containing pathway that facilitates readiness for movement
  • SN pars compacta dopaminergic neurons deteriorate in Parkinson’s disease
Forebrain

- The most anterior and prominent part of the mammalian brain
- Consists of two cerebral hemispheres
- Consists of the outer cortex and subcortical regions
- Each side receives sensory information and controls motor movement from the contralateral side of the body
Forebrain

- Subcortical regions include the diencephalon structures
  - Thalamus
  - Hypothalamus
- Additional structures
  - Pituitary gland
  - Basal ganglia
  - Basal forebrain
  - Hippocampus
Forebrain: Thalamus

- Pair of structures in the center of forebrain
- Main source of input to the cerebral cortex
- Central switching/relay station for all sensory information to the cerebral cortex
Forebrain: Hypothalamus

- Small area near the base of the brain with widespread connections
- Communicates with the pituitary gland to alter the release of hormones
- Damage affects feeding, drinking, sexual behavior, temperature regulation, fighting, activity level and other motivated behaviors

Forebrain: Pituitary Gland

- Master endocrine gland
- Attached to the base of the hypothalamus by a stalk
  - Stalk contains neurons, blood vessels, and connective tissue
- Responds to messages sent by the hypothalamus
- Synthesizes and releases hormones into the bloodstream, which controls hormone release by other glands
Forebrain: Basal Ganglia

- Group of structures lateral to the thalamus
  - Caudate nucleus
  - Putamen
  - Globus pallidus
  - Substantia nigra
  - Subthalamic nucleus
- Also:
  - Nucleus accumbens (often paired with putamen)
  - Ventral pallidum

Forebrain: Basal Ganglia

- Organization
  - Striatum
    - Caudate
    - Putamen
  - Lentiform nucleus
    - Putamen
    - Globus pallidus
Forebrain: Basal Ganglia

- Has many connections to the frontal lobes
- Associated with aspects of memory and emotional expression
- Deterioration primarily causes movement disorders
  - Parkinson’s Disease
  - Huntington’s Chorea
Forebrain: Basal Forebrain

- Group of structures that lie on the ventral surface of the brain
- Receives information from the hypothalamus and basal ganglia
- Includes the nucleus basalis of Meynert
Forebrain: Limbic System

- Forms a border around the brain stem
- Consists of the:
  - Hypothalamus
  - Hippocampus
  - Olfactory bulb
  - Amygdala
  - Cingulate gyrus
- Mediates motivation, emotion, drives, and aggression

Forebrain: Hippocampus

- Large structure located between thalamus and cerebral cortex
- Critical for the formation of new memory
- Connected to the hypothalamus by the fornix
Forebrain: Movement Disorders

• Tics and Tourette’s Disorder
  • Tic = involuntary, rapid, sudden, nonrhythmic, stereotyped motor movement or vocalization
  • TS = multiple motor tics and at least 1 vocal tic

Forebrain: Movement Disorders

• Tics and Tourette’s Disorder
  • Due to:
    • Increased dopamine in the basal ganglia circuits
    • Also implicated:
      • Low serotonin levels
      • Low glutamate levels in the globus pallidus
    • Exacerbated by dopamine agonists
Forebrain: Movement Disorders

• Tics and Tourette’s Disorder
  • Treatment:
    • Neuroleptics that act as dopamine-receptive antagonists
    • Non-neurolopetics are usually tried first to avoid extrapyramidal side-effects

Forebrain: Movement Disorders

• Juvenile Huntington’s Disease
  • Autosomal dominant neurodegenerative disorder involving the basal ganglia and cerebral cortex
  • Excessive number of trinucleotide (CAG) repeats on chromosome 4
    • Having more than 50 CAG repeats is associated with juvenile onset
Forebrain: Movement Disorders

- Juvenile Huntington’s Disease
  - Tend to present with cerebellar symptoms, cognitive deterioration, seizures, and oral/motor dysfunction
  - Adult triad: chorea, cognitive disturbance, and psychiatric/behavioral disturbance
  - Outcome
    - The earlier the onset, the more progressive the disease
    - Eventual death

- Neurologic involvement:
  - Diffuse and regional cerebral atrophy, especially in the caudate nuclei, with loss of GABA-ergic neurons in the head of the caudate
  - For children, also involvement of the cerebellum and globus pallidus
Forebrain: Movement Disorders

- Juvenile Huntington’s Disease
  - Treatment:
    - Dopamine antagonists to reduce chorea
    - Anti-parkinsonian meds to manage rigidity
    - Botox to manage dystonia

Presentation Outline

- Directionality and Orientation
- CNS Basics
- Brain Divisions
- **Cortical Divisions**
- CSF and Ventricular System
- Vasculature and Cerebral Blood Flow
The Cerebral Cortex

- Outer surface of the cerebral hemispheres, divided into two halves
- Composed of grey matter
  - It contains mostly cell bodies and dendrites
  - White matter is formed by axons extending inward from cortex

The Cerebral Cortex

- Neurons from each hemisphere communicate with each other through several bundles of axons
  - Corpus callosum
  - Anterior commissure
- More highly developed in humans than other species
Corpus Callosum

Anterior Commissure
Comparison of Mammalian Brains

The Cerebral Cortex

- Organization of the cerebral cortex
  - Contains up to six distinct laminae that are parallel to the surface of the cortex
  - Cells of the cortex are also divided into columns that lie perpendicular to the laminae
The Cerebral Cortex

- The four lobes of the cortex are:
  - Occipital
  - Parietal
  - Temporal
  - Frontal
Areas of the Human Cortex
The Cerebral Cortex: Occipital

- Located at the posterior end of the cortex
- Also known as the:
  - Striate cortex, or
  - Primary visual cortex
- Highly responsible for visual input
- Damage can result in cortical blindness

The Cerebral Cortex: Parietal

- Between occipital lobe and the central sulcus
- Contains the primary somatosensory cortex
  - Touch sensation
  - Muscle-stretch
  - Joint position information
The Cerebral Cortex: Parietal

- Responsible for processing and integrating information from information sent from muscles and joints about
  - Eye position
  - Head position
  - Body position

The Homunculus
The Homunculus: Motor and Sensory Cortex

- Located on the lateral portion of each hemisphere near the temples
- Important for processing of auditory information
- Responsible for complex aspects of vision, perception of movement and face recognition, and some emotional and motivational behaviors
- Damage may lead to Klüver-Bucy syndrome

The Cerebral Cortex: Temporal
The Cerebral Cortex: Frontal

- Extends from the central sulcus to the anterior limit of the brain
- Contains the:
  - Prefrontal cortex
  - Precentral gyrus

The Cerebral Cortex: Frontal

- Prefrontal cortex
  - Most anterior portion of the frontal lobe
  - Important for executive functions
  - Allows for regulation of impulsive behaviors and the control of more complex behaviors
  - Integration center for all sensory information and other areas of the cortex
Prefrontal Cortex Species Differences

Prefrontal Cortical Injury: The Example of Phineas Gage
Prefrontal Cortical Injury: The Example of Phineas Gage
The Cerebral Cortex

- Various parts of the cerebral cortex do not work independently of each other
  - All areas of the brain communicate with each other
  - There is no single central processor that integrates all functions
Papez Circuit

Reward Circuit
Presentation Outline

• Directionality and Orientation
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• Cortical Divisions
• **CSF and Ventricular System**
• Vasculature and Cerebral Blood Flow

CSF and the Ventricular System

• Cerebral spinal fluid (CSF)
  • Purpose
    • Assists in cushioning the brain
    • Provides a reserve for hormones and nutrition
  • Travels around the brain and spinal cord in subarachnoid space
  • Total volume in an adult = 150 cc
CSF and the Ventricular System

- CSF
  - Formed by the choroid plexus
    - Vascular structure lined with choroid epithelial cells
  - Exits system via foramina in fourth ventricle
    - Lateral foramina of Luschka
    - Midline foramen of Magendie
  - Reabsorbed by arachnoid granulations into dural venous sinuses back into the bloodstream
CSF and the Ventricular System

- CSF fills the:
  - Central canal
    - Channel in the center of the spinal cord
  - Space between the brain and meninges
    - Membranes that surround the brain and spinal cord
  - Four ventricles

CSF and the Ventricular System

- 2 lateral ventricles
  - Communicates with third ventricle via foramen of Monro
- Third ventricle within diencephalon
  - Communicates with fourth ventricle via cerebral aqueduct
- Fourth ventricle
  - Surrounded by pons, medulla, and cerebellum
CSF and The Ventricular System: Hydrocephalus

- Caused by:
  - Obstruction of flow
  - Decreased reabsorption
  - Excess CSF production
- Congenital causes:
  - Neural tube defect
  - Dandy-Walker Syndrome
  - Aqueductal stenosis
  - Intraventricular hemorrhage
CSF and The Ventricular System: Hydrocephalus

• Types:
  • Communicating: impaired reabsorption, obstruction of flow in subarachnoid space, or excess production
  • Noncommunicating: obstruction of flow within ventricular system
  • Normal pressure: chronically dilated ventricles without increased CSF pressure
  • Ex vacuo: excess CSF in region where brain tissue has been lost
Hydrocephalus Ex Vacuo

CSF and The Ventricular System: Hydrocephalus

- Symptoms
  - Headache, nausea, vomiting, cognitive impairment, decreased vision due to increased ICP
  - Magnetic gait and incontinence
  - Eye movement abnormalities
CSF and The Ventricular System: Hydrocephalus

• Symptoms
  • Skull expansion and increased head circumference in infants, with bulging anterior fontanelle
  • For NPH, clinical triad:
    • Incontinence, gait difficulties, and mental decline

CSF and The Ventricular System: Hydrocephalus

• Treatments
  • Ventriculostomy
    • Fluid from lateral ventricles drained to bag
  • VP shunt
    • Shunt tube passed from lateral ventricle out of skull and tunneled under skin to drain into cavity of abdomen
  • Third ventriculostomy
    • Endoscope passes through right frontal lobe, right ventricle, and foramen of Monro to third ventricle
    • Then a perforation is made in the floor of the third ventricle
Ventriculostomy

VP Shunt
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- **Vasculature and Cerebral Blood Flow**

Vasculature and Cerebral Blood Flow

- Primary arterial supply
  - Common carotid arteries
    - Bifurcates into external and internal carotid arteries
      - ICA supplies anterior (ACA) and middle cerebral arteries (MCA)
  - Vertebral arteries join to form basilar artery
    - Bifurcates into posterior cerebral arteries (PCA)
Middle Cerebral Artery

Anterior & Posterior Cerebral Arteries
Vasculature and Cerebral Blood Flow

- Primary arterial supply
  - ACA, MCA, and PCA meet at the circle of Willis
    - Anastomotic ring
    - Immediately ventral to the optic chiasm
    - Assisted by AComA and PComA

Circle of Willis

Middle Cerebral Artery
Vasculature and Cerebral Blood Flow

- Watershed zones
  - Regions between cerebral arteries
  - Most susceptible to ischemia and infarction
  - Can produce:
    - Proximal arm and leg weakness
    - Transcortical aphasia in dominant hemisphere
Vasculature and Cerebral Blood Flow

- **ACA**
  - Supplies most of the cortex on the anterior medial surface of the brain
  - Travels in the interhemispheric fissure
  - Has 2 branches:
    - Pericallosal artery
    - Callosomarginal artery
  - Deep structures supplied by the recurrent artery of Heubner
Vasculature and Cerebral Blood Flow

Anterior cerebral artery

Vasculature and Cerebral Blood Flow

Middle cerebral artery
Vasculature and Cerebral Blood Flow

- MCA
  - Supplies most of the cortex on the dorsolateral convexity of the brain
  - Superior division: supplies cortex above the sylvian fissure
  - Inferior division: supplies region below the sylvian fissure
  - Deep structures supplied by the lenticulostriate arteries
Vasculature and Cerebral Blood Flow

- PCA
  - Supplies the inferior and medial temporal and occipital cortex
  - Deep structures supplied by the thalamoperforator arteries
Disruption of Cerebral Blood Flow

- Ischemic stroke
  - Results in inadequate blood supply to a region of the brain for enough time to cause infarction of tissue
  - Most common type of stroke
  - Resulting from a blood clot or obstruction of an artery
  - Neurons lose their oxygen and glucose supply

Disruption of Cerebral Blood Flow

- Ischemic stroke
  - Transient ischemia attack (TIA)
  - Embolic infarct
  - Thrombotic infarct
  - Hemorrhagic stroke
Disruption of Cerebral Blood Flow

- **TIA**
  - Neurologic deficit lasting < 24 hours
    - Typically only 10 minutes
    - Those longer than an hour are more likely small infarcts
  - Caused by temporary brain ischemia
    - Dissolved embolism or thrombosis
    - Temporary vasospasm

- **Embolic infarct**
  - Piece of material forms in one place and travels through the bloodstream to lodge in and occlude a smaller blood vessel
  - Typically occur suddenly with pain, with maximal deficits at onset
  - Emboli may also include:
    - Air emboli in deep sea divers
    - Septic emboli in bacterial endocarditis
    - Fat emboli in trauma to long bones
Disruption of Cerebral Blood Flow

- **Thrombotic infarct**
  - Blood clot forms locally on a blood vessel wall causing the vessel to occlude
  - May have more of a stuttering/slow course
  - Relatively painless
  - Can lead to the development of emboli
  - May be the result of carotid stenosis, occlusion of sickled cells in SCD

Disruption of Cerebral Blood Flow

- **Intracranial hemorrhage**
  - Typically due to hypertension
  - Occur abruptly
  - Less frequent type of stroke
  - Resulting from a ruptured artery
  - Neurons are flooded with excess calcium, oxygen, and other products
Disruption of Cerebral Blood Flow

- Intracranial hemorrhage
  - Types:
    - Epidural hematoma
    - Subdural hematoma
    - Subarachnoid hemorrhage
    - Intracerebral or intraparenchymal hemorrhage
Disruption of Cerebral Blood Flow

• Epidural hematoma
  • Between dura and skull
  • Due to rupture of middle meningeal artery
  • Symptoms: increased ICP, herniation, changes in consciousness

Disruption of Cerebral Blood Flow

• Subdural hematoma
  • Between dura and arachnoid
  • Due to rupture of bridging veins
  • Symptom: headache, cognitive impairment, unsteady gait, focal dysfunction of underlying cortex
Subdural Hematoma

- Subarachnoid hemorrhage
  - Between arachnoid and pia
  - Two types:
    - Spontaneous: due to arterial aneurysm or bleed from AVM
    - Traumatic: bleeding into CSF from damaged blood vessels from TBI

Disruption of Cerebral Blood Flow
Disruption of Cerebral Blood Flow

- Intracerebral or intraparenchymal hemorrhage
  - Within parenchyma in cerebral hemispheres, brainstem, cerebellum, or spinal cord
  - Two types:
    - Nontraumatic: due to hypertension hemorrhage, brain tumor, vascular malformation
    - Traumatic: due to TBI contusions

Intracerebral Hemorrhage
Disruption of Cerebral Blood Flow

- Edema and excess potassium triggers the release of the excitatory neurotransmitter glutamate
- The overstimulation of neurons leads to sodium and other ions entering the neuron in excessive amounts
- Excess positive ions in the neuron block metabolism in the mitochondria and kill the neuron

Acute Ischemic Stroke in Children

- Incidence:
  - 3/100,000 per year
  - Incidence increasing
    - More sensitive imaging
- Age:
  - Neonates account for 25% of AIS
  - Median age 5 yrs
Acute Ischemic Stroke in Children

- Populations:
  - Male predominance (60%)
  - Predominance in African-American population
- Patient groups:
  - Sickle cell
  - Hemophilia

Acute Ischemic Stroke in Children

- Outcomes:
  - A chain of chemical events results in accumulation of sodium, calcium and zinc ions inside neurons, causing cell death
  - Death in 6%
  - Neurologic deficits in 2/3
  - 20-30% recurrence risk
Reducing Harm from a Stroke

- Tissue plasminogen activator (tPA)
  - Breaks up blood clots and reduces the effects of ischemic strokes
- Research has begun to attempt to save cells in the penumbra (region that surrounds the immediate damage) by:
  - Blocking glutamate synapses
  - Opening potassium channels
  - Using omega-3 fatty acids
Reducing Harm from a Stroke

• Blocking glutamate synapses
  • Excess glutamate may result in the over-excitation of neurons
  • Cannaboidoids have been shown to potentially minimize cell loss after brain damage
    • Decrease the release of glutamate due to their antioxidant or anti-inflammatory actions

Reducing Harm from a Stroke

• Opening potassium channels
  • Reduces overstimulation
• Using omega-3 fatty acids
  • They are a major component of cell membranes
  • May help to block apoptosis and other neural damage
Reducing Harm from a Stroke

• Most effective lab method is to cool the brain
  • Cooling human brain for 3 days improves survival and behavioral functioning
  • A cooled brain (91-97°F) has less activity, lower energy needs and less risk of overstimulation
  • Same with spinal cord injuries

Reducing Harm from a Stroke

• Diaschisis
  • The decreased activity of surviving neurons after damage to other neurons
  • Because activity in one area stimulates other areas, damage to the brain disrupts patterns of normal stimulation
  • Stimulant drugs paired with physical therapy enhanced recovery of stroke victims suffering from diaschisis
  • The use of drugs to stimulate activity in healthy regions of the brain after a stroke may be a mechanism of later recovery
SUMMARY

If the brain were simple enough for us to understand, we would be too simple to understand it.

-Emerson Pugh