Epidemiology

Global and Regional Burden

- Incidence: 69 million people/year globally.
- Common causes: Road traffic accidents, falls, violence, and sports injuries.
- Age groups: High incidence in children, adolescents, and elderly.
- Mortality and morbidity: Leading cause of death and disability among young adults.

Economic Impact

- Healthcare costs: Hospitalization, rehabilitation, and long-term care.
- Societal burden: Loss of productivity and quality of life.

Slide 3: Definition and Pathophysiology

Definition

- Traumatic brain injury (TBI): Disruption of normal brain function caused by external mechanical force.
- Categorized as mild, moderate, or severe based on clinical and imaging criteria.

Pathophysiology

- Primary injury: Direct mechanical damage at the time of trauma.
- Secondary injury: Ongoing cellular damage from hypoxia, ischemia, inflammation, and oxidative stress.

Slide 4: Injury Scales

Glasgow Coma Scale (GCS)

- Scoring system: Eye-opening (E), verbal response (V), motor response (M).
- Categories:
    - Mild TBI: GCS 13–15
    - Moderate TBI: GCS 9–12
    - Severe TBI: GCS ≤8

Other Scales

- Abbreviated Injury Scale (AIS): Focused on the severity of anatomical injuries.
- Marshall CT Classification: Imaging-based classification for structural damage.

Slide 5: Diagnosis

Clinical Evaluation

- Initial assessment: Airway, breathing, circulation (ABC).
- Neurological examination: GCS, pupil reactivity, motor function.

Imaging Modalities

- CT scan: First-line imaging for detecting hemorrhage, edema, and fractures.
- MRI: Superior for detecting diffuse axonal injury and posterior fossa lesions.

Biomarkers

- Emerging role of serum biomarkers (e.g., S100B, GFAP) for injury severity and prognosis.

Slide 6: Management: Acute Phase

Prehospital Care

- Airway protection: Intubation for severe cases.
- Avoiding hypotension and hypoxia: Aggressive fluid resuscitation and oxygen therapy.

In-Hospital Treatment

- Intracranial pressure (ICP) management:
  - Hyperosmolar therapy (mannitol, hypertonic saline).
  - Decompressive craniectomy for refractory ICP.
- Sedation and ventilation: Maintaining $PaCO_2$ 35–45 mmHg.
- Neuroprotection: Temperature control, seizure prophylaxis.

Slide 7: Management: Rehabilitation and Long-term Care

Early Rehabilitation

- Physical, occupational, and speech therapy.
- Cognitive rehabilitation programs.

Long-term Strategies

- Addressing post-traumatic epilepsy, mood disorders, and cognitive decline.
- Multidisciplinary team involvement: Neurologists, psychologists, social workers.

Slide 8: Outcomes and Prognosis

Outcome Predictors

- Severity of injury (GCS, CT findings).
- Age and pre-existing comorbidities.

Functional Outcomes

- Return to baseline: Possible in mild TBI.
- Long-term disability: Frequent in moderate to severe TBI (physical, cognitive, psychological).

Mortality

- Higher in severe cases despite advances in care.

Slide 9: Future Directions and Improvements

Research Areas

- Novel neuroprotective agents: Anti-inflammatory, antioxidant therapies.
- Advanced monitoring: Multimodal monitoring including ICP, brain oxygenation, and metabolism.
- Precision medicine: Biomarker-guided individualized therapy.

Technology Integration

- Artificial intelligence for imaging and outcome prediction.
- Virtual reality and robotics in rehabilitation.

Traumatic Brain Injury (TBI) in American Football Athletes in the USA

Epidemiology

- **High Prevalence in Contact Sports**: American football is a leading sport for TBI among athletes.
- **Annual Incidence**:
    - Over 1 million high school players and 70,000 college athletes at risk annually.
    - Estimated 300,000 football-related concussions per year in the U.S.

Types of TBI

- **Concussions**: Most common, often underreported.
- **Chronic Traumatic Encephalopathy (CTE)**:
    - Linked to repetitive head impacts over time.
    - Associated with cognitive decline, mood disorders, and dementia.

Risk Factors

- Repeated head trauma during practices and games.
- Higher susceptibility in youth athletes due to developing brains.

Clinical and Societal Impact

- Short-term effects: Cognitive impairment, headache, dizziness, and memory loss.
- Long-term effects:

    - Increased risk of neurodegenerative conditions.
    - Psychological issues (e.g., depression, PTSD).
- Financial and legal implications for leagues and institutions.

Prevention and Future Directions

- Improved helmet technology and mandatory concussion protocols.
- Rule changes: Reduced contact during practice and penalties for helmet-to-helmet hits.
- Education: Increased awareness among players, coaches, and parents.

Pathophysiology of TBI – Primary Injury

Primary Injury

- **Definition**: The immediate physical damage to the brain caused by external mechanical forces at the time of trauma.

Mechanisms of Primary Injury

1. **Focal Injuries**:
    - Localized damage due to direct impact or penetrating trauma.
    - Examples:
        - **Contusions**: Brain bruising at the site of impact.
        - **Hematomas**: Epidural, subdural, or intracerebral bleeding.
    - Typical Imaging Findings: Hemorrhage, fractures, or skull deformities.
2. **Diffuse Injuries**:
    - Widespread damage due to inertial forces (e.g., rotational or shear stress).
    - Examples:
        - **Diffuse Axonal Injury (DAI)**: Stretching or tearing of axons.
        - Common in high-velocity accidents.
3. **Mechanical Forces**:
    - Compression: Localized pressure on brain tissue.
    - Acceleration/Deceleration: Rapid movement changes causing axonal stretching.

Pathological Outcomes

- Disruption of neuronal, glial, and vascular structures.
- Immediate loss of cellular homeostasis.
- Mechanical disruption of the blood-brain barrier (BBB).

Clinical Significance

- Severity of primary injury influences the onset and magnitude of secondary injury.

Pathophysiology of TBI – Secondary Injury

Secondary Injury

- **Definition**: Progressive, delayed damage initiated by cellular and molecular cascades following the primary insult.

Mechanisms of Secondary Injury

1. **Hypoxia and Ischemia**:
    - Reduced oxygen delivery and impaired cerebral perfusion.
    - Mechanisms:
        - Cerebral edema leading to increased intracranial pressure (ICP).
        - Hypoperfusion due to vascular compromise or systemic hypotension.
2. **Inflammatory Cascade**:
    - Activation of microglia and astrocytes.
    - Release of pro-inflammatory cytokines (e.g., TNF-α, IL-6).
    - Blood-brain barrier disruption exacerbates leukocyte infiltration.
3. **Oxidative Stress**:
    - Overproduction of reactive oxygen species (ROS) and reactive nitrogen species (RNS).
    - Causes lipid peroxidation, protein degradation, and DNA damage.
4. **Excitotoxicity**:
    - Excessive release of glutamate leading to sustained neuronal depolarization.
    - Results in intracellular calcium overload and activation of destructive enzymes.
5. **Mitochondrial Dysfunction**:
    - Impaired ATP production exacerbates energy failure.
    - Contributes to cell death via necrosis or apoptosis.

Pathological Outcomes

- Cytotoxic and vasogenic edema.
- Progression to neuronal and glial cell death.
- Secondary ischemia and delayed hemorrhage.

Clinical Implications

- Targeted interventions (e.g., hyperosmolar therapy, neuroprotective agents) aim to mitigate secondary injury and improve outcomes.

Traumatic Brain Injury (TBI) Scales for Outcome Prediction

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1. Glasgow Outcome Scale (GOS)

- **Purpose**: Assesses long-term functional outcomes.
- **Scale Categories**:
    1. **Death**: Patient does not survive.
    2. **Vegetative State**: No awareness of self or environment.
    3. **Severe Disability**: Requires assistance for daily living.
    4. **Moderate Disability**: Independent but with deficits.
    5. **Good Recovery**: Resumption of normal life with possible minor deficits.
- **Usage**: Commonly applied 6 months post-injury to gauge recovery.

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2. Extended Glasgow Outcome Scale (GOSE)

- **Purpose**: Provides a more detailed assessment compared to GOS.
- **Expanded Categories**:
    - Adds subcategories (e.g., upper/lower severe disability) for granular evaluation.
- **Advantages**: Greater sensitivity to subtle functional improvements or declines.

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3. Abbreviated Injury Scale (AIS) and Injury Severity Score (ISS)

- **AIS**: Rates injuries on a scale from 1 (minor) to 6 (unsurvivable).
- **ISS**:
  - Combines AIS scores from multiple body regions.
  - Ranges from 1 to 75, with higher scores indicating more severe injuries.
- **Relevance in TBI**:
  - High ISS scores often correlate with poor neurological outcomes.

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4. Ranchos Los Amigos Scale

- **Purpose**: Measures cognitive and behavioral recovery.
- **Scale**:
  - Levels range from 1 (no response) to 10 (purposeful and independent behavior).
- **Application**: Useful in tracking recovery during rehabilitation.

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5. Marshall CT Classification

- **Purpose**: Classifies TBI based on CT scan findings.
- **Categories**:
  - Diffuse injury (grades I-IV).
  - Mass lesions (e.g., evacuated or non-evacuated hematomas).
- **Prognostic Value**: Strongly correlates with mortality and morbidity.

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6. Prognostic Models

- **IMPACT (International Mission for Prognosis and Analysis of Clinical Trials in TBI)**:
  - Uses data from GCS, CT findings, and age to predict outcomes.
- **CRASH (Corticosteroid Randomisation After Significant Head Injury)**:
  - Incorporates clinical and demographic data for mortality and disability prediction.

Conclusion

- Outcome scales and classification systems guide **prognosis** and **treatment planning**.
- Combining clinical, radiological, and functional tools enhances predictive accuracy for patient outcomes.

Clinical Evaluation of Traumatic Brain Injury (TBI)

Primary Survey: Immediate Life-Threatening Concerns

Purpose: Identify and manage life-threatening conditions quickly.

1. **Airway**:
   - Assess for airway obstruction (e.g., blood, foreign objects).
   - Ensure cervical spine stabilization during airway management.
2. **Breathing**:
   - Check respiratory rate, effort, and oxygen saturation.
   - Identify pneumothorax, hemothorax, or inadequate ventilation.
3. **Circulation**:
   - Assess hemodynamic status (pulse, blood pressure, capillary refill).
   - Look for signs of shock due to external or internal bleeding.
4. **Disability (Neurological Assessment)**:
   - Perform **Glasgow Coma Scale (GCS)** evaluation.
   - Assess pupil size, reactivity, and lateralizing signs.
5. **Exposure and Environmental Control**:
   - Fully expose the patient to assess for other injuries.
   - Prevent hypothermia by covering the patient once evaluation is complete.

Secondary Survey: Detailed and Comprehensive Examination

Purpose: Detect less obvious injuries and assess the extent of brain and systemic damage.

1. **History (AMPLE)**:

    - **A**: Allergies.
    - **M**: Medications.
    - **P**: Past medical history.
    - **L**: Last meal or drink.
    - **E**: Events leading to injury.
2. **Head-to-Toe Examination**:
    - **Head**: Check for scalp lacerations, skull fractures, or facial injuries.
    - **Neck**: Evaluate for cervical spine injuries and neck vein distension.
    - **Chest/Abdomen**: Identify concurrent thoracic or abdominal trauma.
3. **Focused Neurological Examination**:
    - Reassess **GCS** for changes in mental status.
    - Monitor cranial nerve function and extremity motor/sensory responses.
4. **Imaging Studies**:
    - Obtain **non-contrast CT scan** for intracranial injuries.
    - Consider MRI for diffuse axonal injury or posterior fossa lesions.
5. **Monitoring**:
    - Place patient on continuous ECG, pulse oximetry, and blood pressure monitoring.

Guidelines for Imaging Modalities in Traumatic Brain Injury (TBI) Diagnosis

Key Recommendations for Imaging Modalities
Imaging plays a crucial role in diagnosing TBI and determining its severity. Below are evidence-based guidelines from organizations like the Brain Trauma Foundation (BTF), American College of Radiology (ACR), and other authoritative sources.

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1. Initial Imaging: Non-Contrast CT Scan

- **First-Line Modality**: Non-contrast computed tomography (CT) is the gold standard for acute TBI.
    - Rapid assessment of hemorrhage, fractures, edema, midline shift, and mass effect.
- **Indications for Immediate CT**:
    - GCS ≤13 on admission.
    - Focal neurological deficits.
    - Persistent vomiting (>2 episodes).
    - Severe headache or signs of skull fracture.
    - Post-traumatic seizures.
    - Suspected penetrating head injury.

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2. Magnetic Resonance Imaging (MRI)

- **Second-Line Modality**: Used when CT findings are inconclusive or for detailed evaluation of brain parenchyma.
- **Indications**:
    - Suspected diffuse axonal injury (DAI).
    - Posterior fossa or brainstem lesions.
    - Prolonged post-traumatic amnesia or cognitive deficits.
    - Delayed deterioration with a normal CT.

Preferred MRI Sequences:

- Gradient echo (GRE) or susceptibility-weighted imaging (SWI): Detect microhemorrhages.

- Diffusion-weighted imaging (DWI): Evaluate ischemic changes and axonal injury.

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3. Advanced Imaging Techniques

- **CT Angiography (CTA) and Venography (CTV)**:
  - Indicated for suspected vascular injuries (e.g., dissection, aneurysm, or dural sinus thrombosis).
- **Perfusion CT/MRI**:
  - To assess cerebral blood flow in secondary injury and monitor ischemia.

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4. Ultrasonography (Point-of-Care Ultrasound - POCUS)

- Limited role in TBI but useful in resource-limited settings or prehospital care.
- Can evaluate optic nerve sheath diameter (ONSD) for raised intracranial pressure (ICP).

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5. Emerging Modalities

- **Positron Emission Tomography (PET)**: Used in research to study brain metabolism.
- **Magnetoencephalography (MEG)**: Evaluates functional brain disturbances post-TBI.

Clinical Decision Rules for Imaging

1. **Canadian CT Head Rule**:
   - Designed for patients with minor head injuries.
   - Advises CT if high-risk factors like suspected skull fracture, GCS <15 at 2 hours, or age ≥65 years are present.
2. **New Orleans Criteria**:
   - Focuses on symptoms such as headache, vomiting, or drug/alcohol intoxication.
3. **PECARN Rule (Pediatric TBI)**:
   - Specific for children to reduce unnecessary radiation exposure.

Considerations in Special Populations

- **Pediatrics**: Favor clinical observation over imaging for mild TBI unless clinical decision rules indicate imaging.
- **Elderly**: Lower threshold for imaging due to increased risk of subdural hematomas and anticoagulant use.

Emerging Role of Serum Biomarkers in TBI: S100B and GFAP

Introduction to Biomarkers in TBI

- Biomarkers are measurable substances in blood reflecting tissue damage and physiological processes.
- In TBI, biomarkers help assess **injury severity**, predict **prognosis**, and guide clinical decisions.

Key Biomarkers

1. S100B (S100 Calcium-Binding Protein B)

- **Source**: Primarily released from astrocytes in the central nervous system (CNS).
- **Utility**:
  - Elevated levels correlate with **blood-brain barrier disruption**.
  - High sensitivity for detecting **mild TBI**, especially in ruling out significant injuries.
- **Clinical Use**:
  - Widely used in Europe as part of the Scandinavian Neurotrauma Guidelines.
  - Reduces unnecessary CT scans in mild TBI.

2. GFAP (Glial Fibrillary Acidic Protein)

- **Source**: Released from astrocytes during structural CNS damage.
- **Utility**:
  - Highly specific for **moderate-to-severe TBI**.
  - Associated with **intracranial lesions** visible on CT/MRI.
- **Clinical Use**:
  - FDA-approved in conjunction with UCH-L1 (ubiquitin carboxyl-terminal hydrolase-L1) for assessing mild TBI.

Advantages of Biomarkers

- Non-invasive and rapid testing.
- Potential to complement imaging for **diagnostic accuracy**.
- Aid in **monitoring secondary injury progression**.

Limitations and Future Directions

- **Challenges**:
  - Variability in biomarker thresholds and kinetics.
  - Limited availability in routine clinical settings.
- **Future Research**:
  - Standardization of cutoff values for better integration into practice.
  - Development of multi-biomarker panels for comprehensive assessment.
