Introduction

- The surgical management of PBI aims to
  - Save lives
  - Avert secondary brain insults such as
    - Intracranial hypertension
    - Infection
    - CSF leakage
    - Timely rehabilitation
    - Reintegrate the patient into pre-trauma social life
History

- Early 15 century; Giovanni De Vigo to control bleeding and deal with salpetre advocated cauterization of missile wounds
- In this era indication for surgical trephination of skull were not defined
  - Head wounds were managed in an orthopedic fashion
- John Hunter (1728-1793) advocated trephination to relieve the pressure of pus or blood on the brain

- Until the end of 19th century surgical mortality of missile head wounds was appallingly high
- And trephination was dreaded because of significant intracranial sepsis
- By the turn off the century; introduction of antisepsis, asepsis, anesthesia, cerebral localization and roentgenography
  - Intracranial approach to pathologies became credible
• When Cushing move to Hospital in France with nurse anesthetist “Miss Gerard” (1918) the stage was set to broach the dura mater and explore the brain substance with impunity.
• Cushing introduced meticulous exposure of the entry and exit wounds, together with debridement of the scalp, skull, dura and brain.
• Instead of packing the wound, Cushing closed the scalp watertight.
• Cushing was able to reduce surgical mortality to 28.8%, even without antibiotics.
Treatment of PBI entered a new era during World War II along with suction, electrocautery, penicillin and sulfa medication and dura closed watertight.

In the 1970s, some civilian centers began to introduce less aggressive debridement in Lebanon and Israel.

**Ballistics**

Science of the motion of projectile through a gun barrel, subsequently through a medium such as air, and into or through target.

Divided into:
1. **Interior ballistics**:
   - Deals with the pressure, volume and temperature of gases after combustion of the powder charge
2. **Exterior ballistics**:
   - Deals with shape, weight, caliber and the velocity of a projectile, air resistance and gravity
3. Terminal ballistics

- Is the behavior of the projectile after it penetrates the target
- Affect depend on the impact velocity and surface, density and angle of impact, fragmentation, detonation, combustion and incendiary effect.
- Tissue with higher densities are prone to more devastating injuries

The projectile exerts three types of pressure on the brain

1. Juxtamissile pressure
   - Immediate vicinity of the bullet
2. Longitudinal strong shock wave pressure
   - Generated immediately upon impact
3. Ordinary pressure waves
   - Produced by kinetic energy transfer to the brain
   - This results in a temporary cavity immediately behind the bullet
Yaw

- Rifling results in spin;
- Which is rotation of the bullet around its longitudinal axis
- Spin keeps bullet’s nose forward
- Change in density distribution, the nose may deviate from the longitudinal axis and immediately returns back to its original position
- In denser mediums yaw occurs much easier and is more devastating

Tumbling

- Rotate 180 degrees and then flip back to its original position by the spin
Temporary cavity

- High velocity missile enters a gelatin,
- Kinetic energy of the bullet produces a temporary cavity
- The gelatin cube expands, pulsates several times and returns back to normal
- Leaving a small streak of the projectile path called “permanent cavity”
- The temporary cavity has a negative pressure and would expand and collapse several times before it stop and produces the permanent cavity
Pathogenesis and Pathology

- **Scalp**
  - Contact scalp injuries (0.5 cm.) leave stellate skin tears due to expanding gun smoke
  - Near contact scalp injuries (6”) will not tear the scalp but singe skin or hair
  - Close range injuries (2.5’), characteristic is tattoo.
  - Long range injuries, usually do not have the footprints of gunpowder on the skin
  - Long range scalp injuries vary significantly
    - They could be a pinhole, a through and through injury, a wide gaping wound or a gutter

Skull

- Whether penetrated or not, skull injuries are quite intriguing
- Tangential injuries could transmit a massive amount of kinetic energy to the brain
- Should CT scan of head to define the extent of brain damage
- Inner table of the skull is more susceptible to fractures
Penetrating or perforating injuries send a shower of fragment skull into the brain with debris.

- Parietal bone is the most frequent region of skull injury.
- Penetrating injuries of air sinuses are risk of CNS infection.
- Orbitofacial and pterional injuries increase the likelihood of traumatic aneurysm.
- Injuries at the skull base are close to the basal cisterns and can predispose to CSF leaks and CNS infections.

**Dura**

- Since intact dura is the most important barrier against extension of infection into the intracranial cavity.
- Dura laceration are either in simple perforations or stellate laceration.
- A heated projectile can cause retraction of the dural edges.
- The dura may be repaired with either autograft or allograft with watertight repair.
Brain

- The degree of parenchymal damage depends on the amount of K.E deposited in the brain
- Low energy fragments, the degree of damage may by compatible with survival and reasonable recovery
- High velocity PBIs are usually more devastating
- Ordinary pressure waves and resultant temporary cavity almost always make survival impossible

Wound profile

- Defined by CT, with clinical exam (GCS)
- For dictate therapeutic management strategy
- Perforating wounds have a worse prognosis than penetrating and tangential wounds
- Bullets traversing two or more planes
- Intraventricular hematoma
- SAH
Clinical presentation

- Military conflict the victim of PBI is young (20s)
- Civilian victim are a decade older
- In Israeli experience in Lebanon up to 48% were comatose (GCS<10)
- In Iran-Iraq War GCS 3-8 was 24%
- In civilian literature GCS 3-8 was 48-94%
- 74% of civilian victims of PBI die at the scene of the accident

Clinical presentation

- 11% die within 3 hours
- 7% die later
- Mortality of 92%
- 10-50% of PBI are hypotension
- 50-66% have abnormal pupillary response to light
- A significant with coagulopathy
Evaluation
Skull Series

- Show skull fractures, the path of the bullet, evidence of retained fragments
- If CT is available, skull radiographs are unnecessary

CT scan

- Mainstay to evaluation of PBI
- Clear picture of the wound profile and important prognostic information
MRI scan

- Still not very well-defined

Cerebral angiography

- When the projectile has penetrated near the synvian fzissue,pterion or face and evidence of intracerebral hematoma

Surgical management

Prophylactic antibiotics

- Although not supported by any prospective randomized controlled study
- Since these wounds are considered to be contaminated
- Use of antibiotic, sulfa and penicillin during world war II
- The use of prophylactic broad-spectrum antibiotics is appropriate for patients with PBI
12/13/11

**SELECTION OF SURGICAL TECHNIQUE**

a. Uncomplicated, small entry wound in a conscious patient

Treatment of small entrance bullet wounds to the head with local wound care and closure in patients whose scalp is not devitalized and those who have no ‘significant’ intracranial pathology is recommended. Note: Although the term ‘significant’ is not yet definitive, the volume and location of the brain injury, evidence of mass effect (displacement of the midline or compression of basilar cisterns from edema or hematoma), and the patient’s clinical condition all pertain to significance. (Guidelines for the management of Penetrating Brain Injury; Aarabi et al., 2001.)
b. Extensive wounds with significant damage to the scalp, skull, dura and brain

Treatment of more extensive wounds with non-viable scalp, bone of dura require more extensive debridement before primary closure or grafting to secure a water-tight wound.

(Guidelines for the Management of Penetrating Brain Injury; Aarabi et al., 2001.)
c. Presence of mass effect
In the presence of significant mass effect, debridement of necrotic brain tissue and safely accessible bone fragments is recommended. Intracranial hematomas with 'significant' mass effect, surgical debridement of the brain is an option, but remains controversial.

d. Involvement of paranasal sinuses or mastoid air cells
Repair of an open-air sinus injury with watertight closure of the dura is recommended. Clinical circumstances dictate the timing of the repair.
(Guidelines for the Management of Penetrating Brain Injury; Aarabi et al., 2001.)
e. Removal of retained fragments

Routine surgical removal of fragments lodged distant from the entry site and re operation solely to remove retained bone or missile fragments are not recommended.

(Guidelines for the Management of Penetrating Brain Injury; Aarabi et al., 2001.)

f. Craniectomy versus craniotomy

In the presence of significant fragmentation of the skull, debridement of the cranial wound with either craniectomy or craniotomy is advised.

(Guidelines for the Management of Penetrating Brain Injury; Aarabi et al., 2001.)
### Complications

#### Infection

- Whitaker, 1916. (prior to Cushing) PBI was treated with open drainage and packing
  - Had an infection rate of 58.8%
  - 83% with infection die
- During World War I, Cushing introduced the principle of meticulous debridement of scalp, skull, and brain and watertight closure of scalp
  - Reduced infection rate
  - Over the past century has been 5-23%

- Most of contaminating organisms are skin flora
  - Staphylococcus epidermidis
- The rate of contamination of incurred
  - Scalp wound 35-96.4%
  - Bone 20-80%
  - Brain track 28-78%
- Risk factors to deep CNS infection
  - Low GCS
  - The degree of tissue destruction
  - CSF leak (most importantly)
Post traumatic epilepsy
- Major cause of disability and inadequate social integration
- Military PBI if F.U. to 15 years, nearly 50% develop seizures
- This incidence is at least twice in severe TBI due to closed head injury
- Early seizures within the first week up to 2-8.9%
- When analyzed in a univariate model
  - Mode of injury, GCS, motor deficit, dysphagia, infection, early seizures GOS, tranventricular injury, motor deficit at F.U.
  - Were significantly related to the incidence of PTE

In a multivariate model
- Only GOS and motor deficit at F.U.
- Were significant factors
- Seizures were most often generalized with or without focal onset
- Although there is no prospective study to indicate the efficacy of prophylactic anti-seizure in PBI
- It has been recommended in the first week after injury
**Traumatic intracranial aneurysm**

- Between 2 - 33% of PBI develop traumatic intracranial aneurysm (TICA)
- 20% of all TICA due to PBI
- Wound profile can help in determining the probability of a TICA
  - Fragments crossing one dural compartment
  - Penetrating pterion or face
  - Associated with intracranial hematomas

- The majority of traumatic aneurysm due to PBI have a false sac made of clotted blood “pseudoaneurysm”
- Pseudoaneurysm, the parent artery had to be repaired, coiled, clipped as a way of permanently curing the aneurysm.
- Recommended to manage TICA before rupture and cause ICH
Lt ICA

Lt ICA post embolization