Objectives

- History
- Mechanical Properties of Projectiles
- Anatomic considerations
- Vascular injury, laryngeal injury*, esophageal injury*, Neuropathy
- Diagnosis
  - Signs and symptoms
  - Imaging Techniques
- Management
  - Zone Algorithm
  - “No Zone” Approach
- Cases
Historical Perspective

• Earliest description >5,000 years ago
• Homer’s *Iliad* – Achilles lances Hector in suprasternal notch
• Ambrose Pare (1510-1590)
  • First documented treating a patient by ligating the carotid artery and jugular vein of a soldier with a bayonet wound.
• 1800’s more documented cases of ligating lacerated carotids
Historical Perspective

Wartime Advancements

- Civil War – WWI
  - Observation
- WWII
  - Exploration if platysma penetrated
- Korea
  - Mobile Army Surgical Hospitals (MASH)

<table>
<thead>
<tr>
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### Historical Perspective

#### Wartime Advancements

- **Civil War – WWI**
  - Observation
- **WWII**
  - Exploration if platysma penetrated
- **Korea**
  - Mobile Army Surgical Hospitals (MASH)

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Historical Perspective

Wartime Advancements

• Civil War – WWI
  • Observation

• WWII
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**Historical Perspective**

**Wartime Advancements**

- **Vietnam**
  - High velocity rifles
- **Gulf Wars, Croatia, Balkans, OIF**
  - Improvised Explosive Devices
  - Body Armor
- **Civilian Experience**
  - Handguns, knives, etc

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Penetrating Neck Trauma - Basics

- Penetrating Neck Injury is present in 5-10% of all trauma cases. (Hom DB)
- Multiple vital structures present
  - Vascular system
  - Air passages
  - Upper Gastrointestinal passages
  - Neurologic system
Penetrating Neck Trauma - Basics

- Penetrating Neck Injury is present in 5-10% of all trauma cases
- Multiple vital structures present

- Vascular system
  - Carotid, Jugular, subclavian, innominate, aortic arch
- Air passages
  - Pharynx, Larynx, trachea, lungs
- Upper Gastrointestinal passages
  - Pharynx, esophagus
- Neurologic system
  - Spinal cord, cranial nerves, peripheral nerves, brachial plexus, sympathetic chain
Mechanism of Injury

- Stab injuries – Knife, razor blades, glass, etc
- Predictable damage pathway
  - Stab vs. Projectile Injury
    - Higher incidence of subclavian laceration
    - Lower incidence of spinal cord injury
- Projectile
  - Handgun
  - Rifle
  - Shotgun
Kinetic Energy of Projectile

\[ KE = \frac{1}{2} \text{Mass} (V_{\text{entry}} - V_{\text{exit}})^2 \]

- Handguns – Lower muzzle velocity (210-600 m/s)
- Shotguns – Low muzzle velocity (300 m/s)
- Rifles – High muzzle velocity (760 – 2,000 m/s)

- Muzzle velocity > 610 m/s
  - Create a temporary cavity up to 30 times the missile size.
Wound Profile

Figure 115-1. Characteristic wound profile of a high-velocity, soft-point rifle bullet. Note characteristic large temporary and permanent cavities with massive tissue disruption. The wound profile of a conventional copper-jacketed, high-velocity bullet would reveal a similar temporary cavity. (From Fackler M, Bellamy R, Malinowski J. The wound profile: illustration of the middle-tissue interaction. J Trauma. 1988;28(Suppl):21.)

http://www.youtube.com/watch?v=9uEXeXXbDYg
Projectile Injury Mechanics

- Kinetic Injury of Missile: more energy = more damage

- Velocity: higher velocity = more KE, see above

- Yaw — “tumbling”
  - More tumble = more transmitted energy, larger damage path

- Casing — alters flight dynamics and penetration dynamics
  - Strong metal jacket allows through and through injury
  - Lead casings leave a trail on Xray
Projectile Injury Mechanics

• Bullet Tip
  • “Expanding bullet” – hollowpoint, softnose
    • More energy transmission and more soft tissue injury

• Entry/Exit wound, pathway through tissue
Wound Profile

Cummings Ch. 115
Anatomic Considerations

- Three anatomic zones described as a method of classifying injury.

Figure 115-3. The three zones of the neck are seen on this frontal view. The shaded area represents the portion that some authors consider zone I but that others label zone II. (From Carducci B, Lowe RA, Dalsey W. Penetrating neck trauma: consensus and controversies. Ann Emerg Med. 1986;15:208.)

Cummings Ch. 115
Zone I Structures

• **Boundaries:**
  - Clavicles and sternal notch up to cricoid cartilage

• **Vasculature**
  - Arch of Aorta, Innominate vessels
  - Subclavian vessels
  - Proximal Carotid Arteries
  - Vertebral Arteries

• **Aerodigestive**
  - Trachea, Lung apices
  - Esophagus
  - Thoracic duct

• **Neurologic**
  - Brachial plexus, spinal cord
Zone 1 Considerations

- Dangerous Area
  - Close proximity of vasculature to thorax
- Osseous Shield
  - Protects against injury
  - Surgical Access difficult
- Surgical Access
  - May require sternotomy or thoracotomy
  - Mandatory exploration is NOT recommended
- Mortality – 12%

Bagheri, SC 2008
Anatomic Zones

Figure 115-3. The three zones of the neck are seen on this frontal view. The shaded area represents the portion that some authors consider zone I but that others label zone II. (From Carducci B, Lowe RA, Dalsey W. Penetrating neck trauma: consensus and controversies. Ann Emerg Med. 1986;15:208.)

Cummings Ch. 115
Zone II Structures

- **Boundaries**: Cricoid cartilage to angle of mandible
- **Vasculature**: Common Carotid, Internal and External, Jugular veins
- **Aerodigestive**: Larynx, Hypopharynx, Proximal Esohpagus
- **Neurologic**: Cranial Nerves, spinal cord, sympathetic chain
Zone II Considerations

• Largest and most commonly involved area ~60-75%

• No Osseous Shield

• Surgical Access “Easy”
  • Proximal and Distal control of vasculature “easy”
  • Fascial layers may tamponade

• Elective vs Mandatory Exploration
Anatomic Zones

Figure 115-3. The three zones of the neck are seen on this frontal view. The shaded area represents the portion that some authors consider zone I but that others label zone II. (From Carducci B, Lowe RA, Dalsey W. Penetrating neck trauma: consensus and controversies. Ann Emerg Med. 1986;15:208.)

Cummings Ch. 115
Zone III Structures

- **Boundaries:**
  - Angle of mandible to base of skull

- **Vasculature**
  - Internal Carotid
  - External Carotid
  - Vertebral Artery
  - Prevertebral venous plexus
  - Jugular veins

- **Aerodigestive**
  - Oral cavity, Pharynx

- **Neurologic**
  - Cranial nerves (trunk of VII), spinal cord
Zone III Considerations

- Dangerous Area
  - Proximity of vasculature to skull base

- Osseous Shield
  - Protects against injury
  - Surgical Access difficult

- Surgical Access
  - Mandibulotomy
  - Craniotomy

- Mandatory exploration is NOT recommended

Bagheri, SC 2008
Zone III Considerations

• Pearls
  • Cranial neuropathies may be indicative of injury to nearby vasculature
  • Frequent examination oral cavity
Physical Examination

- ABC’s
- Hard Signs
- Airway signs
- Vascular signs
- Neurologic signs
- Esophageal signs
Physical Examination

- ABC’s
- Hard Signs
- Airway signs
- Vascular signs
- Neurologic signs
- Esophageal signs
Hard Signs

• Indications for Mandatory *Immediate* Surgical Exploration

<table>
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<tr>
<th>Table 1. <em>Indications for Immediate Surgery after Penetrating Neck Trauma</em></th>
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<tbody>
<tr>
<td>• Shock</td>
</tr>
<tr>
<td>• Pulsatile bleeding</td>
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<tr>
<td>• Expanding hematoma</td>
</tr>
<tr>
<td>• Unilateral extremity pulse deficit</td>
</tr>
<tr>
<td>• Audible bruit or palpable thrill</td>
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<tr>
<td>• Airway compromise</td>
</tr>
<tr>
<td>• Wound bubbling</td>
</tr>
<tr>
<td>• Extensive subcutaneous emphysema</td>
</tr>
<tr>
<td>• Stridor</td>
</tr>
<tr>
<td>• Hoarseness</td>
</tr>
<tr>
<td>• Signs of stroke/cerebral ischemia</td>
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</table>

Shiroff AM 2013
Physical Examination

• ABC’s
• Hard Signs
• Airway signs
• Vascular signs
• Neurologic signs
• Esophageal signs
Airway Signs

- Respiratory distress
- Stridor
- Hoarseness
- Hemoptysis
- Tracheal Deviation
- Subcutaneous Emphysema
- Sucking Wound

Fikker BG 2004
Physical Examination

- ABC’s
- Hard Signs
- Airway signs
- Vascular signs
- Neurologic signs
- Esophageal signs
Signs of Vascular Injury

- Hematoma
- Persistent Bleeding
- Absent Carotid Pulse
- Bruit
- Thrill
- Hypovolemic Shock
- Change of Sensorium
- Neurologic Deficit

Munera F 2000
Physical Examination

• ABC’s
• Hard Signs
• Airway signs
• Vascular signs
• Neurologic signs
• Esophageal signs
Signs of Neurologic Injury

- Hemiplegia
- Quadriplegia
- Coma
- Cranial Nerve Deficit
- Change of Sensorium
- Hoarseness
- *Signs of stroke/cerebral ischemia
Physical Examination

- ABC’s
- Hard Signs
- Airway signs
- Vascular signs
- Neurologic signs
- Esophageal signs
Signs of Injury to Hypopharynx/Esothagus

- Subcutaneous Emphysema
- Dysphagia
- Odynophagia
- Hematemesis
- Hemoptysis
- Tachycardia
- Fever

- Most commonly missed zone II injury
- Significant *Delayed* morbidity and mortality

Rathlev NK 2007
Objectives

- History
- Mechanical Properties of Projectiles
- Anatomic considerations
- Vascular injury, laryngeal injury*, esophageal injury*, Neuropathy
- Diagnosis
  - Signs and symptoms
  - Imaging Techniques
- Management
  - Zone Algorithm
  - “No Zone” Approach
- Cases
Imaging Techniques

- Angiography
- Carotid Ultrasound
- CT Angiography
- MRI/MRA
- Direct laryngoscopy, rigid bronchoscopy, rigid esophagoscropy
- Flexible endoscopy
- Gastrograffin/Barium swallow
Management – Classical “Zones” Approach

• In 1979 Roon and Christensen classified injuries by site of penetration using external landmarks – sternal notch, cricoid, angle of mandible

• Hard signs present any zone → OR

• Injury to Zones I or III – Angiography and endoscopy
• Injury to Zone II – mandatory exploration if platysma penetrated
Classical Approach

Operative Exploration/Repair

Traditional Approach

Identify Zone of Injury

Zone I
1. Angiogram: Arch and Great Vessels
2. Bronchoscopy
3. Esophagoscopy/Esophagography

Zone II
- Immediate Neck Exploration
  OR
1. Angiography
2. Bronchoscopy
3. Esophagoscopy/Esophagography

Zone III
1. Angiography
2. Bronchoscopy
3. Esophagoscopy/Esophagography

Operative Exploration/Repair

Multi-Det Angiogram
Positive
Directed Angiogram
Positive
Endoscopy as in Zone II

Shiroff AM 2013
Management – Selective “Zones” Approach

• Scrutiny of mandatory Zone II exploration
  • Negative exploration rates range from 50-70%
  • Missed injuries
  • Increased hospital stay

• 1993 – Atteberry described 53 patients with zone II injury managed selectively
  • 19 pts immediate exploration based on physical exam findings
  • 34 pts observed: angiography/endoscopy performed
    • No missed vascular injuries
Brief Review

- Injury to Zones I or III – Angiography and endoscopy
- Injury to Zone II – mandatory exploration if platysma penetrated

Shiroff AM 2013
Rapid cases – Hard signs absent
Controversy: Mandatory Vs. Selective

- Numerous studies comparing, no clear winner

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<th>Mandatory</th>
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<td>Diagnosis</td>
<td>Potential life-threatening injuries can be missed by the preoperative workup.</td>
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<td>Skill and resources</td>
<td>Selective management requires more skill, manpower, experience, and judgment; additional special diagnostic procedures are also required.</td>
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<td>Hospital stay</td>
<td>Length of stay is similar for observation and negative exploration.</td>
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<tr>
<td>Delay</td>
<td>If occult injuries are delayed, morbidity and mortality will increase.</td>
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<td>Patient care</td>
<td>Active observation requires continuous availability of experienced trauma medical staff for monitoring the patient.</td>
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## Controversy: Mandatory Vs. Selective

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<td>Diagnosis</td>
<td>Most major injuries can be diagnosed preoperatively; routine exploration can miss some injuries.</td>
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<td>Skill and resources</td>
<td>Selective care will reduce unnecessary explorations by a surgeon inexperienced with trauma.</td>
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<tr>
<td>Hospital stay</td>
<td>No advantage of negative exploration.</td>
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<td>Delay</td>
<td>Delay has not been shown to significantly increase morbidity and mortality of occult injuries.</td>
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<td>Patient care</td>
<td>Selective management emphasizes the concept of collaboration among trauma team members and reduces unnecessary surgical exploration.</td>
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“No Zone” Approach

• Scrutiny of Traditional Zones Approach
  • “Maximally Invasive” – risks/cost/operator error/operator availability of angiography and endoscopy
  • Developed prior to the development of modern imaging techniques

• No Zone Approach
  • Unstable patients treated the same as Traditional Approach
  • Zone description eliminated, injury to any of three zones in stable patient is evaluated with CT/CTA
Fig. 1. Algorithm for the modern management of penetrating neck injuries.

**Hard Signs**
- Airway compromise
- Shock
- Pulsatile bleeding
- Expanding hematoma
- Unilateral pulse deficit
- Bruit or pulsatile thrill
- Extensive SQ Air
- Stridor/Hoarseness
- Signs of Stroke

Penetrating Neck Injury

Platysma Violation

Yes

Local Wound Care/Observe/Discharge

No

Pressure Control of Hemorrhage

Rapid Sequence Intubation

Operative Exploration/Repair

Yes

Hard Signs for Immediate Surgery**

No

Modern "NO ZONE" Approach

Multi-Detector CT Angiography

Positive

Directed Angiography or Endoscopy as Indicated

Negative

High Risk Trajectory

Positive

Traditional Approach

Identify Zone of Injury

Zone I
- 1. Angiogram: Arch and Great Vessels
- 2. Bronchoscopy
- 3. Esophagoscopy/Esophagography

Zone II
- 1. Immediate Neck Exploration
- OR
- 2. Bronchoscopy
- 3. Esophagoscopy/Esophagography

Zone III
- 1. Angiography
- 2. Bronchoscopy
- 3. Esophagoscopy/Esophagography

Operative Exploration/Repair

Shiroff AM 2013
“No Zone” Approach

• No Zone Approach
  • Unstable patients treated the same as Traditional Approach
  • Injury to any of three zones in stable patient is evaluated with CT/CTA

Shiroff AM 2013
“No Zone” Approach

- Described by Gracias et al Arch Surg 2001
  - Demonstrated at 50% decrease in the use of angiography and 90% decrease in the use of endoscopy

- Identification of missile trajectory guides subsequent diagnostic and therapeutic interventions.
  - If remote from vital structures the no further workup
CT Angiography

Munera F 2004
CT Angiography

Advantages

• Superior image quality
• Readily available, quick
• Limited interuser variability
• Safe
• Shows surrounding structures

Limitations

• Poor timing of contrast load
• Patient movement
• Metallic artifact
• Body habitus
• Not therapeutic
Mechanism of injury is emphasized
Thorough physical examination is key
Hard signs indicate need for immediate surgical exploration of any zone
Stable patients with Zone I and III injury undergo angiography and endoscopy
Stable patients with Zone II injury undergo surgical exploration or angio/endoscopy
Evaluating with CT Angiography may allow for less utilization of services and is effective and reliable.

Some cases
Case 1

• 27 yo male baking cookies with his grandma when a stranger walks in the house, stabs him, and runs away.
  • Bleed profusely initially but seems to have slowed
  • Arrives in ED
• Subclavian intimal flap seen on CTA, angiography allowed for stenting over flap to re-establish flow.
Case 2

• 22 yo male walking his son home from church in Prague when a stranger shoots him with a handgun and runs away. EMT arrived to scene and pt bleeding profusely and unconscious.
• Intubated and transferred to trauma center.
Department of Radiology
General University Hospital
and
First Faculty of Medicine
Charles University
in
Prague
Case 3

- 45 yo male takes his friend to a firing range, he’s never shot a gun before.
- Friend accidentally shoots him in the neck above cricoid with a 9mm, throws some band-aids on and drives to the ED.
Case 4

- 28 yo male hunting on public land that is densely populated with hunters. He is inadvertently shot with a 12 gauge slug from 30 meters away.
Case 5

• 18 yo male in a bar stabbed from behind mandibular angle coursing anteriorly
  • Examination vitals stable
  • Oral cavity – no parapharyngeal or retropharyngeal hematoma
  • Asymmetric palatal rise, voice is hoarse, and ipsilateral shoulder is weak.
  What vessel is at risk for injury?
References

- Hom DB, Maisel RH. Ch. 115. Penetrating and blunt trauma to the neck. Cummings Otolaryngology Head and Neck Surgery.


- Images as cited or hyperlinked in powerpoint.