Trauma Radiology: An Algorithmic Approach

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ALGORITHMIC EVALUATION OF COMPLEX TRAUMA

I. Introduction

II. Trauma: Catastrophic and Critical Diagnoses

III. Strategic Pathways for Diagnostic Imaging
  - Head and Face
  - Axial Skeleton and Spinal Cord
  - Thoracic Injuries
  - Abdominopelvic Injuries
  - Appendicular Skeleton and Extremity Injuries

IV. Case Illustrations

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Introduction

Trauma remains the leading cause of death for children and young adults under 40 despite recent advances in management. The contemporary evaluation and management of the trauma patient require parallel efforts to assess the patient clinically and radiologically. The selection of radiological investigations remains a source of controversy. Advancing imaging modalities yield diagnoses previously overlooked; medicolegal concerns influence clinical decisions; decision rules and protocols designed to reduce unnecessary costs, radiation exposure, and clinical delays can seem complex, contradictory, and excessively rigid; resources are progressively limited. In reviewing these issues, a system is described that may prove useful in clinical practice, with a critical review of the advantages and disadvantages of various radiological modalities. While a set of algorithms is advocated, it is underscored that this will vary depending on the facilities available. It is appropriate however to be aware of the limitations of the radiological techniques that are utilized in trauma on a daily basis and to have a knowledge of how selective use of advanced imaging modalities will improve patient care.

1. **Consider** the high risk differential diagnosis, on the basis of clinical history, physical examination, and laboratory studies.

2. **Concurrently** stabilize, initiate imaging sequence, and/or contact appropriate surgical consultants.

3. **Confirm** benign etiologies *directly*, or indirectly *after* formal exclusion of the catastrophic differential diagnosis.
How are traumatic catastrophic conditions defined?

- **Catastrophic** conditions are those which have a significant risk of mortality, if the diagnosis is emergently missed.

- **Critical** traumatic conditions are those which have a significant risk of morbidity, if the diagnosis is delayed (e.g., cervical spine injuries, occult fractures, or internal derangements).
7 Catastrophic traumatic conditions

- Intracranial hemorrhage
- Aortic transections and vascular injury
- Myocardial contusion and laceration
- Pericardial hemorrhage
- Pneumothorax
- Solid organ laceration (liver, spleen, adrenal, renal, and pancreas)
- Bowel and bladder perforation
7 Critical Injuries: Axial and Extremity Trauma

- Cervical spine fractures
- Shoulder dislocations
- Epiphyseal avulsion fractures
- Navicular fractures
- Pelvic fractures
- Femoral neck impaction fractures
- Lisfranc fractures
General Vital Sign Indications for Catastrophic Differential Diagnosis

- 1. Tachycardia or bradycardia (heart rate <50)
- 2. Tachypnea or bradypnea (respiratory rate <7)
- 3. Significant pyrexia or hypothermia
- 4. Hypotension and hypertension
- 5. Acute hypoxia
- 6. Pain severity
Local Vital Sign Indications for Traumatic Differential Diagnosis

- Glasgow Coma Score
  - Adult
  - Pediatric
- Visual acuity
- Injury site related pain
- Peripheral pulses
- Peripheral pulse oximetry
- Peripheral capillary refill
Clinical Catastrophic Criteria

- Acuity, severity, progression, persistence, refractory, atypical or unexplained:
  - Critical acute chest symptoms (i.e., chest pain, chest pressure, or respiratory distress)
  - Critical abdominal and pelvic clinical symptoms (i.e., pain, nausea, vomiting, diarrhea, distension, bleeding, or irritability)
  - Selective physical findings (absence of breath sounds, cardiac murmurs; pericardial friction rub; altered bowel sounds, masses or peritoneal signs).
  - Aberrant laboratory, electrocardiographic, or plain radiographic abnormalities.
Imaging Modalities

- Conventional Radiographs and Special Views
- CT: Incremental, Spiral, Angiographic
- US: Gray Scale, Color Doppler, Amplitude Angiography
- MR: MRI and MRA
- Arterial Catheterization
Head and Facial Trauma: Diagnostic Strategy

Catastrophic Craniofacial Findings

Clinical Information
- Vital Signs
- History
- Neurologic Examination

Standard Diagnostic Testing
- 1. Laboratory
- 2. XR

Advanced Imaging Options
- 1. CT/CTA
- 2. MRI
- 3. Angiography
Axial Skeletal Trauma: Diagnostic Strategy

Catastrophic Axial Skeletal Findings

Clinical Information
- Vital Signs
- History
- Neurologic Examination

Standard Diagnostic Testing
- 1. Laboratory
- 2. XR

Advanced Imaging Options
- 1. CT/CTA
- 2. MRI
- 3. Angiography
## Thoracic Imaging: Critical Diagnoses

<table>
<thead>
<tr>
<th>STRUCTURE</th>
<th>CRITICAL DDx</th>
<th>IMAGING MODALITY</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pulmonary Artery</td>
<td>Laceration</td>
<td>CTA/CT</td>
</tr>
<tr>
<td>Aorta</td>
<td>Transection</td>
<td>CTA/CT</td>
</tr>
<tr>
<td></td>
<td>Dissection</td>
<td></td>
</tr>
<tr>
<td>Pulmonary Parenchyma</td>
<td>Pneumothorax</td>
<td>CXR</td>
</tr>
<tr>
<td></td>
<td>Pulmonary contusion</td>
<td>CTA/CT</td>
</tr>
<tr>
<td>Pericardium</td>
<td>Pericardial Effusion/Hemorrhage</td>
<td>CT (stable) US (unstable)</td>
</tr>
<tr>
<td>Cardiac</td>
<td>Contusion</td>
<td>CTA/CT (stable)</td>
</tr>
<tr>
<td></td>
<td>Penetrating injury</td>
<td>US (unstable)</td>
</tr>
</tbody>
</table>
Thoracic Imaging: Radiologic Classification

Critical Chest Diagnoses by Modality

CT/CTA
- Pulmonary Parenchyma
- Pulmonary Artery
- Aorta and Coronaries
- Pericardium
- Pleura
- Musculoskeletal and Diaphragm
- Mediastinum

US
- Pericardium
- Cor

Angiography
- Cardiovascular
Thoracic Imaging: Radiologic Sequence

Imaging evaluation of acute chest trauma divides into three typical paths:

1. Chest Radiograph: general survey
2. US (e.g., myocardial contusion and pericardial effusions)
3. CT/CTA (e.g., pulmonary contusion, aortic transection, and pericardial injury)
Acute Plain Radiographic Abnormalities: Traumatic Chest Protocol

- Pulmonary
  - Pneumothorax
  - Pleural Effusions or Hemothorax
  - Pulmonary edema
  - Multilobar consolidation
  - Mediastinal shift

- Esophageal
  - Pneumomediastinum

- Cardiac, Aortic and Pericardium
  - Widened mediastinum
  - Undefined aortic arch
  - Left apical pleural capping
  - Cardiomegaly versus pericardial effusion (tamponade)
  - Superior rib fractures
Thoracic Trauma: Diagnostic Strategy

Catastrophic Chest Findings

Clinical Information
- Vital Signs
- Cardiovascular and Pulmonary History
- Auscultation

Standard Diagnostic Testing
- 1. Laboratory
- 2. ECG
- 3. CXR

Advanced Imaging Options
- 1. US
- 2. CT/CTA
- 3. Angiography
## Regional Differential Diagnosis in Acute Abdominal Pain

<table>
<thead>
<tr>
<th>Right inferior thorax</th>
<th>Mediastinal</th>
<th>Left inferior thorax</th>
</tr>
</thead>
<tbody>
<tr>
<td>Right upper quadrant</td>
<td>Epigastric</td>
<td>Left upper quadrant</td>
</tr>
<tr>
<td>Right lower quadrant</td>
<td>Inferior abdominal</td>
<td>Left lower quadrant</td>
</tr>
<tr>
<td>Pulmonary contusion*</td>
<td>GI perforation*</td>
<td>Pericardial effusion*</td>
</tr>
<tr>
<td>---------------------</td>
<td>-----------------</td>
<td>-----------------------</td>
</tr>
<tr>
<td>Hemothorax*</td>
<td>Cardiac contusion*</td>
<td>Pneumothorax*</td>
</tr>
<tr>
<td>Hepatic laceration*</td>
<td>GI contusion*</td>
<td>Splenic laceration*</td>
</tr>
<tr>
<td>Renal laceration*</td>
<td>Pancreatic laceration*</td>
<td>Perinephric hematoma*</td>
</tr>
<tr>
<td>Pelvic fractures*</td>
<td>Bladder injury*</td>
<td>Ovarian cyst rupture*</td>
</tr>
</tbody>
</table>

Regional Differential Diagnosis in Acute Abdominal Pain
Classical Algorithm for Abdominal Trauma

- Acute Abdomen
  - History and PDx
  - Laboratory
  - Conventional Imaging
  - Consultation
  - Initial X-sectional Imaging
    - CT
    - US
  - Secondary Imaging
    - Nuclear Medicine
    - GI Contrast Studies
    - Angiography
Parallel Algorithm for Abdominal Trauma

1. History and PDx
2. Laboratory
3. Conventional Imaging
   1. CXR
   2. Abdominal Series
4. Imaging
   1. Color Doppler
   2. Power Doppler
   3. IV, Oral, Rectal
   4. CT Angiography
5. Consultation
   1. US
   2. CT
   3. CT Angiography
Acute Plain Radiographic Abnormalities: Traumatic Abdominal-Pelvic Protocol

- Gas collections
  - Subdiaphragmatic free air
  - Air in the lesser sac (retroperitoneal perforation on upright lateral abdomen)
  - Gas at both endoluminal and extraluminal mural boundary (free air)
  - Intrahepatic gas (penetrating injury)
  - Intravascular gas (penetrating injury)
  - Subcutaneous emphysema (pneumothorax)

- Metallic or other radiopaque foreign body

- Bowel walls
  - Small bowel greater than 3 cm or large bowel greater than 6 cm (bowel obstruction, extrinsic compression, or ileus)
  - Gastrointestinal or colonic mural thickening (> 3 mm; contusion, mural hematoma, or edema from tear)
# Clinical Pathways for Emergent Abdominal Trauma: Structural Criteria

<table>
<thead>
<tr>
<th>STRUCTURE</th>
<th>EXAMPLE</th>
<th>IMAGING MODALITY</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fluid-filled</td>
<td>Vesicles, ducts</td>
<td>US</td>
</tr>
<tr>
<td>Gas-filled</td>
<td>GI tract</td>
<td>CT</td>
</tr>
<tr>
<td>Solid organs</td>
<td>Liver, Pancreas, Spleen, or Kidneys</td>
<td>CT</td>
</tr>
<tr>
<td>Vascular</td>
<td>Abdominal Aorta</td>
<td>US (unstable)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>CT (stable)</td>
</tr>
<tr>
<td>Reproductive</td>
<td>Pregnancy</td>
<td>US</td>
</tr>
</tbody>
</table>
# Abdominal Trauma: Imaging Selection

<table>
<thead>
<tr>
<th>PDx / Lab</th>
<th>RUQ T</th>
<th>RLQ T</th>
<th>LUQ T</th>
<th>LLQ T</th>
<th>ADX T</th>
<th>CVA T</th>
<th>Trauma Vascul.</th>
<th>Diffuse T</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hematuria</td>
<td>CT+ I(O)</td>
<td>CT+ I(O)</td>
<td>CT+ I(O)</td>
<td>CT+ I(O)</td>
<td>CT+ I(O)</td>
<td>CT+ I(O)</td>
<td>CT+ I(O)</td>
<td>CT+ I(O)</td>
</tr>
<tr>
<td>Lipase +</td>
<td>CT+ I(O)</td>
<td>CT+ I(O)</td>
<td>CT+ I(O)</td>
<td>CT+ I(O)</td>
<td>CT+ I(O)</td>
<td>CT+ I(O)</td>
<td>CT+ I(O)</td>
<td>CT+ I(O)</td>
</tr>
<tr>
<td>Elevated LFT</td>
<td>CT+ I(O)</td>
<td>CT+ I(O)</td>
<td>CT+ I(O)</td>
<td>CT+ I(O)</td>
<td>CT+ I(O)</td>
<td>CT+ I(O)</td>
<td>CT+ I(O)</td>
<td>CT+ I(O)</td>
</tr>
</tbody>
</table>

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Abdominopelvic Trauma: Diagnostic Strategy

Catastrophic Abdominal Findings

Clinical Information
- Vital Signs
- History
- Auscultation

Standard Diagnostic Testing
- 1. Laboratory
- 2. ECG
- 3. KUB

Advanced Imaging Options
- 1. US
- 2. CT/CTA
- 3. Angiography
Universal Decision Rule in Axial and Extremity Injuries

- If focal skeletal tenderness is demonstrated, conventional radiographs.
  - Comparison to contralateral view in children (or use of Keats).
  - CT (or MRI) for atypical, asymmetric, askew, or avulsed findings.
  - Advise patients that “occult fractures and internal derangements cannot be excluded, and interval evaluation may be required.”

- Splint
  - Hard collar for cervical spine strain.
  - Appropriate splint for extremity injuries.

- Formal radiologic interpretation in less than 24 hours.

- Formal follow-up:
  - Diminished or asymmetric range of motion in children, concurrent orthopedic discussion or consultation.
  - Instability: concurrent orthopedic discussion or consultation.
  - Interval evaluation in adults in <7 days with appropriate specialist (e.g., orthopedist, maxillofacial, neurosurgical, or otolaryngologist).
Appendicular Skeletal Trauma

**Catastrophic Appendicular Findings**

**Clinical Information**
- Vital Signs
- History
- Extremity Examination

**Standard Diagnostic Testing**
- 1. Laboratory
- 2. XR

**Advanced Imaging Options**
- 1. CT/CTA
- 2. MRI
- 3. Angiography
Workshop Case Illustrations
Trauma: Universal Diagnostic Strategy

Catastrophic Findings

Clinical Information
- Vital Signs
- History
- Physical Examination

Standard Diagnostic Testing
- 1. Laboratory
- 2. ECG
- 3. XR

Advanced Imaging Options
- 1. US
- 2. CT/CTA
- 3. MRI


3. Radiation Risks and Pediatric Computed Tomography (CT): A Guide for Health Care Providers, National Cancer Institute (USA) and Society for Pediatric Radiology, 2002 (modified for Table 1).
After a closed head injury, with transient loss of consciousness, a 2 year old female infant has persistent nausea and vomiting. Imaging should include:

1. None
2. Skull films
3. Head CT scan
4. Head MRI