OBJECTIVES

- To learn the grades of splenic and hepatic injuries & the CT findings that may contraindicate conservative management.
- To discuss the surgical classifications of hepatic, splenic, pancreatic injuries.
- To learn the clinical signs and the CT findings that suggest angiography.
- To discuss late potential complications resulting from conservative management.

ABDOMINAL TRAUMA

- Trauma: 3rd leading cause of death in USA
- Leading cause of death in persons < 40yrs
- Abdominal trauma accounts for 10% of trauma related deaths
- 85 billion dollars per year
ABDOMINAL TRAUMA

- Advances in treatment of trauma pts:
  1. EMS: defines the level of trauma I-II
  2. CT: high sn, & sp. in detecting & defining injury
- Spiral CT: allows quicker scanning with an intense bolus contrast
- Multidetector row helical CT:
  - 3-6 times faster than single slice
  - Greater axial coverage, and spatial resolution
  - Improves image quality for MPR

Accuracy of CT in diagnosis of Abdominal Trauma: 98%

WHO GETS CT?

- Performed in trauma pts with inadequate or equivocal abdominal PE
- Altered mental status
- (ETOH, drugs, head injury)
- "Distracting injuries" -- pelvic, or other bony fractures
- "ALL LEVEL 1 TRAUMAS"

Who gets CT?

Scanner located near the trauma bay — allows CT evaluation on seriously injured pts who may have not been scanned in the past.

20 y.o. hypotensive trauma pt, s/p cardiac arrest just prior to CT
Note: lack of enhancement of kidneys
ABDOMINAL TRAUMA: CT

- Major advantage of helical MDCT: increased speed of examination
- Rapid successive CT scans of various body parts can be performed on the same pt
- Reconstructions allow better evaluation of small injuries, and improved coronal and sagittal reformations

HEMOPERITONEUM

- Easily detected on CT -- should prompt a thorough search for visceral organ injury
- Starts near the site of injury and spreads along traditional pathways
- Morrison’s pouch—
  - Most dependent peritoneal recess in upper abdomen
  - Most common site of blood collection in upper abdominal trauma

LEARNING POINT: SCAN THE PELVIS

Blood in the Belly: CT Findings of Hemoperitoneum
Lubner, Menias et al. Radiographics 2007. 27, 109-125

HEMOPERITONEUM

- Perihepatic & perisplenic spaces
- Paracolic gutters
- Pelvis--cul de sac--most dependent recess of the entire peritoneal cavity
- Massive amount of fluid can collect in pelvis with little blood seen at other sites

LEARNING POINT: SCAN THE PELVIS—in every trauma patient

Blood in the Belly: CT Findings of Hemoperitoneum
Lubner, Menias et al. Radiographics 2007. 27, 109-125
**HEMOPERITONEUM**

- Appearance variable-dependent on age, and physical state of blood
- *Active extravasation* -- 180 HU -- isodense to the aorta -- usually surrounded by a large hypodense hematoma

**Mesenteric injury**

**Lumbar Artery Injury**

**Active Arterial Extravasation**
HEMOPERITONEUM

"Sentinel clot sign"—adjacent focal high attenuation clotted blood
• A marker for the injured organ

SPLENIC RUPTURE; SENTINEL CLOT SIGN

Hemorrhage may be hypodense
• < 30 HU in anemic patients

HYPODENSE HEMOPERITONEUM—SPLENIC RUPTURE IN HEMOPHILIAC

• "Hematocrit effect"—fresh blood within a hematoma - serous fluid layering on dependent clot
Blunt Splenic Injury
- Most common injured organ in blunt abdominal trauma
- >95% associated with hemoperitoneum
- More complex injuries now imaged due to the close proximity of the CT scanner to the trauma bay
- CT → 98% accurate

Spleen: Normal arterial enhancement
- Heterogeneous appearance of splenic enhancement on early post-injection scans—may need to get delayed images

MDCT of Splenic Injury
- 4 principle types of splenic injury
  1. Hematoma
     - Subcapsular
     - Intraparenchymal
  2. Laceration/fracture
  3. Active hemorrhage
  4. Vascular injuries
     - Pseudoaneurysm
     - A-V fistula
**Blunt Splenic Injury**

- Evolution of management
- Fueled by potential benefits of splenic immune preservation
  - Decrease of overwhelming postsplenectomy infections
- Nonoperative management (NOM)
  - Standard of care in last 2 decades
  - Replaced splenorrhaphy as the most common means of splenic salvage
  - Remains the decision of the trauma surgeon
  - Timely availability of the angiography team

**Blunt Visceral Injury**

- American Association for the Surgery of Trauma (AAST)
  - Committee formed to compare outcome, treatment protocols, and standardize reporting visceral injuries
  - Developed injury severity score
  - Based on anatomic depiction of visceral disruption
  - Includes length, number of lacerations, surface area involved, and extent of subcapsular or intraparenchymal hematoma

**Spleen Injury AAST Classification**

<table>
<thead>
<tr>
<th>GRADE</th>
<th>CT Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Subcapsular, nonexpanding hematoma &lt;10% surface area</td>
</tr>
<tr>
<td></td>
<td>Capsular tear, nonbleeding, &lt; 1cm depth</td>
</tr>
<tr>
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<td>Subcapsular, nonexpanding hematoma 10-50% or &lt; 3cm</td>
</tr>
<tr>
<td></td>
<td>Capsular tear &lt; 3 cm</td>
</tr>
<tr>
<td>3</td>
<td>Subcapsular, &gt; 50% surface area</td>
</tr>
<tr>
<td></td>
<td>Ruptured subcapsular hematoma</td>
</tr>
<tr>
<td></td>
<td>≥ 3cm depth on trabecular vessels</td>
</tr>
<tr>
<td>4</td>
<td>Ruptured intraparenchymal hematoma</td>
</tr>
<tr>
<td></td>
<td>Laceration of segmental or hilar vessels with major</td>
</tr>
<tr>
<td></td>
<td>&gt; 25% devascularization</td>
</tr>
<tr>
<td>5</td>
<td>Completely shattered spleen</td>
</tr>
<tr>
<td></td>
<td>Hilar vascular injury that devascularizes spleen</td>
</tr>
</tbody>
</table>
Management of Splenic Injury

- Ultimately dictated by the patient's condition, severity of organ injury, and the experience of the surgeon

Nonoperative management
- Requires patient hemodynamic stability
- SBP > 90, HR < 110
- Age < 55
- CT GRADE 1-2
  - Smith JS et al. Surgery 1996
- ** Controversial

MDCT of Splenic Injury

Subcapsular Hematomas — crescentic collections that flatten/indent the spleen

GRADE 3 SUBCAPSULAR HEMATOMA, >50% surface area

MANAGED SURGICALLY

SBP 80, HR 130
+ femur fracture
MDCT SPLENIC INJURY

- Several CT grading systems for splenic injury published. No CT grading scheme enables prediction of the need for splenic surgery nor can predict the patient’s outcome of non-operative management.

- Limits of CT: “single snapshot in time”—no documentation of the progression of injury.

Spleen Injury AAST Classification

GRADE 2 LACERATION, <3 CM
GRADE 2 INJURY, DELAYED RUPTURE
GRADE 4 INJURY > 25% DEVASCULARIZED
Spleen Injury AAST Classification

- Surgical Grade Limited—
  - No account taken for dynamic CT findings
- Active Extravasation **
- Contrast Blush
- Pseudoaneurysm/ A-V fistula

** High association with failed nonoperative management
(Federle MP at al Radiology 1998; 206: 137-42)

Upgrades the grade of Injury if visualized on CT
(Shapiro MJ, et al Journal of Trauma, 1999)

Spleen Injury AAST Classification

- Contrast Blush
  - ** ** High association with failed nonoperative management
    (Federle MP at al Radiology 1998; 206: 137-42)

MDCT of Splenic Injury

- ACTIVE BLEEDING/ EXTRAVASATION
  - Irregular, linear areas of high density
  - Isodense to the arterial vasculature
  - Surrounded by hematoma
  - Within the splenic parenchyma, subcapsular space, or peritoneum
  - Increase in size — delayed phase
MDCT of Splenic Injury

Grade 5 Splenic Pedicle Avulsion—Active Extravasation, delayed

MDCT of Splenic Injury

Grade 5 Splenic Pedicle Avulsion—Active Extravasation, to OR
MDCT of Splenic Injury
- Grade 5 Splenic Pedicle Avulsion—Active Extravasation
- to OR....

MDCT of Vascular Injury
- Pseudoaneurysm = AV fistula on MDCT
  - Well-defined focal areas high attenuation
  - Isodense to arterial vasculature
- Becomes isodense on delayed phase
  - Does not increase in size

AV-Fistula ➔ Well-defined focal high attenuation areas, isodense on delayed
MDCT of Splenic Injury

- Surgical Management
  - Devascularized spleen
  - Shattered Spleen
  - ?? Active Extravasation**
    - Management differs between surgical centers

?? Active Extravasation**
Management differs between surgical centers
MDCT of Splenic Injury

- Active Extravasation
- Management differs between surgical centers

Complications

- 20% - 30% in NOM
  - Hemorrhage
  - Rupture
  - Splenic Abscess
  - Splenic Infarction

GRADE 1 LACERATION
GRADE 1 LACERATION
Æ
NOM
GRADE 1 LACERATIONÆÆ
DELAYED RUPTURE

Complications

- SPLENIC INFARCTION

(Haan JM et al. J. Trauma 2004;56:542-47)
Complications

Grade 3 Injury
- Subcapsular Hematoma / Laceration
- NOM

Followup
- Subcapsular Abscess

FOLLOWUP IMAGING
- What is the role of routine follow-up imaging in stable Pt. with no change in their clinical status?
- Early in treatment course
  - Valuable in higher-grade injuries
  - Re-evaluate for pseudoaneurysms
  - Prevent patients from failure of NOM
- Determine return to activity after injury
  - Higher overall costs
  - Document healing prior to return to unrestricted activity, not thoroughly studied → but still practiced
  - ? Change clinical management

MDCT of Liver Injury
- 2nd most common organ injured in blunt trauma
- Most common abdominal injury leading to death
- Relatively fixed position, segments 6, 7, 8
- Lacerations typically perivascular → “Adds to bloody mess”
90% of hepatic injuries involve the right hepatic lobe.
Constitutes most of the liver volume.
Posterior segment readily accessible to blunt impact from the ribs and spine.
Relative fixation of the coronary ligaments.

Left hepatic injuries much less common.
Occur with a forceful, direct blow to the epigastrium.
High association with damage to the retroperitoneum - pancreas, duodenum, and the transverse colon.

Left Hepatic Laceration (with mesenteric injury)
LIVER INJURY

- Hepatic lacerations -- **perivascular**
- Paralleling the right and middle hepatic veins and posterior branches of the right portal vein
- Typically extend to the periphery of the liver

**Bear claw** pattern -- parallel linear, jagged lacerations radiating from the hilum

Liver Laceration

"bear claw sign"
MDCT of Liver Injury

Evolution in management
- In the past, most hepatic injuries treated surgically.
- Majority of liver injuries stopped bleeding at surgical exploration
- >2/3rds of operations non-therapeutic

CT Imaging
- Great impact on management
- Marked reduction in number of non-therapeutic surgeries

Periportal Edema
Hematoma
  - Subcapsular
  - Intraparenchymal
Laceration/fracture
Active hemorrhage
Vascular injuries
  - Pseudoaneurysm
  - A-V fistula
  - Devascularization

Liver Injury AAST Classification

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<td>Subcapsular/parenchymal hematoma or laceration &gt; 10 cm lobar destruction or devascularization</td>
</tr>
<tr>
<td>5</td>
<td>Global destruction or devascularization</td>
</tr>
<tr>
<td>6</td>
<td>Hepatic avulsion</td>
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</table>
Liver Injury AAST Classification

- Active Extravasation
  - Intraperitoneal
  - Intra-hepatic

MDCT of Liver Injury

- Active Extravasation
  - Intraperitoneal
    - Indicates active and massive bleeding
    - May require emergent surgery
    - Combined surgical and radiologic approach required in the TX of pts with high-grade liver injuries
    - "Damage control" Laparotomy

- Intra-hepatic
  - Intact liver capsule
  - Usually Pseudoaneurysm
  - A-V fistula
  - Self-limiting hemorrhage
  - NOM

If seen on CT—warrants either embolization or operative repair
MDCT of Liver Injury
Can CT Guide Management in Blunt Liver Trauma?

- Direct correlation between CT grade and hepatic bleeding, failed NOM, and remote complications
  - Grade 3-4 injuries more likely to bleed than Grades 1-2
- Injuries involving hepatic vein(s)
  - 3.5x more frequently associated with major hepatic bleeding than those without venous involvement

MDCT of Liver Injury
Can CT Guide Management in Blunt Liver Trauma?

- Direct correlation between CT grade and hepatic bleeding, failed NOM, and remote complications
  - Grade 3-4 injuries more likely to bleed than Grades 1-2

IF HEMODYNAMICALLY STABLE

Grade 4 injuries that involve hepatic vein → Angio
Any Grade liver injury with CT finding of Vascular injury → Angiography
  - Active hemorrhage/extravasation
(Poletti et al, Radiology 2000:216:418-427)
MDCT of Liver Injury

Grade 4 Injury
1. Active Extravasation
2. Near RHV

Angiography (Poletti et al, Radiology 2000)

Any Grade liver injury with CT finding of Vascular injury → Angiography

Grade 4 injuries that involve hepatic vein → Angiography
Complications

- NOM→ similar complications to those injuries seen which are managed operatively
  - Delayed hemorrhage → most common
  - Bile leak / biloma / hemobilia
  - Hepatic / Gallbladder necrosis
  - Perihepatic / intrahepatic abscess

  * Higher the Injury Grade the higher the incidence of complications (21% of Grade 4; 63% Grade 5 injuries)

Predicting Bile Leaks

- Grade of liver injury is unreliable at predicting bile leak
- HIDA or ERCP not always available immediately
- Location of laceration more important than size

CT PREDICTOR FOR BILE LEAK

- Grade of liver injury is unreliable at predicting bile leak
- Location of laceration more important than size

Follow up — Hematoma and small biliary leak
Grade of liver injury is unreliable at predicting bile leak.
Location of laceration more important than size.

Location of laceration class as peripheral, central (or mixed).
Extension of laceration to medial or lateral edge of the liver (or both).

Liver lacerations extending to both the medial and lateral surfaces of the liver have the highest incidence of bile leak requiring intervention.

Followup CT/ERCP: Large Biliary Leak; Biloma.
**MDCT of Liver Injury Complications**

- Hepatic Infarction

**Follow up CT -> Hepatic Necrosis**

**MDCT of Liver Injury Complications**

GRADE 5 Liver Injury -> Hepatic Infarction

**Pancreatic Injuries**

- Uncommon: ~ 2% of all blunt trauma patients
- 20% mortality rate: most occur within 48 hours
- Early deaths due to hemorrhage from vascular injury
- Delayed complications such as fistula, abscess, hemorrhage, sepsis contribute to high mortality rate
**Pancreatic Injury**
- Most common mechanism in adults: MVC
- Most common mechanisms in children:
  - Bicycle accident, child abuse
- Vulnerable to crush injury against spine:
  - 2/3 injuries occur in the pancreatic body, neck
  - 1/3 injuries occur equally in the head and tail

**Pancreatic Trauma**
- Isolated injuries are rare, 90% association with other injury:
  - Liver → left lobe
  - Stomach
  - Duodenum
  - Spleen
  - Left Kidney

**PANCREATIC INJURY**
- CT - 67-85% sn in injuries < 12 hrs
- Laceration plane obscured by adjacent hemorrhage
- Close apposition of the lacerated fragments
- Adjacent unopacified proximal jejunal loops

Repeat CT scan maybe necessary 12-24hrs later
**PANCREATIC INJURY**

- Nonspecific but suggestive signs
- infiltration of peripancreatic fat
- thickening of the left anterior renal fascia
- tracking of fluid between the splenic vein and pancreas
- fluid in the anterior pararenal space or lesser sac

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**PANCREATIC INJURY**

- Fracture/ transection: linear hypodense region oriented perpendicular to long axis of pancreas

- Most commonly in pancreatic neck
  - Where the pancreas overlies the spine

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**Pancreatic Lacerations: Superficial vs. Deep**

- Superficial laceration less than 50% deep
- No pancreatic duct injury at surgery

- Deep laceration >50%
- Pancreatic duct injury
Pancreatic Duct Disruption

- Critical determination:
  - NO: conservative management
  - YES: surgery, stenting
- Complications
  - Abscess 25%
  - Fistula 50%

Imaging the Pancreatic Duct

- MDCT may demonstrate duct directly
- Injury also predicted by depth of laceration
- Pancreatography: MRCP, ERCP
  - Advantages of MRCP:
    - Non-invasive, no radiation
    - Used mostly for follow-up
  - Advantages of ERCP:
    - Complete visualization of pancreatic duct
    - Ability to diagnose injury and guide therapy
      - Stent placement

Complications

Delayed complications: fistula, abscess, pseudocyst, hemorrhage, sepsis contribute to high mortality rate
**Complications**

Delayed complications: fistula, abscess, pseudocyst, hemorrhage, sepsis contribute to high mortality rate

- Post-traumatic pancreatitis with pseudocyst

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**Post-traumatic pancreatitis with pseudocyst**

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**Conclusion**

- Discuss the grades of splenic and hepatic injuries & the CT findings that may contraindicate conservative management.
- Discuss the surgical classifications of hepatic, splenic, pancreatic injuries.
- Discuss clinical signs and the CT findings that suggest angiography.
- Discuss late potential complications resulting from conservative management.