Liver Trauma

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Liver injuries in children: The role of selective non-operative management
A. Landau, A.B. van As, A. Numanoglu, A.J.W. Millar and H. Rode
Trauma Unit, Department of Pediatric Surgery, Red Cross Children's Hospital.
Injury 2006. 37:66-71
Blunt liver trauma

- The liver is the most frequently injured solid organ following blunt abdominal injury in children.
- Selective non-operative management of blunt liver trauma in haemodynamically stable patients is well established and accepted by most paediatric surgical centres.
- Surgical intervention in paediatric liver trauma is based on haemodynamic instability that persists despite ongoing resuscitation.
- Biliary injuries are often missed until clinically manifest.
- Major liver trauma is still associated with a significant mortality.
Patterns of liver injury

Peritoneal and vascular fixed attachments
Pliable chest wall & exposure in a protuberant abdomen of a child

The direction, velocity, grade and site of blunt force as well as the position and motion of the victim contribute to the pattern and severity of the injury

- Subcapsular haematoma/contusion
- Parenchymal damage/laceration
- Hepatic vascular disruption – contrast extravasation
- Bile duct injury – intrahepatic & extrahepatic
Schematic diagram of the liver noting the structures at each potential site of injury.
Patterns of injury

Oblique right chest [pedestrian traffic]

Anterior acceleration injury - laceration to the L or R of the Falciform ligament
Patterns of injury

Deceleration injury [falls from a height, pedestrian traffic]

Compression injury [roll over]
Natural History of different types of injury

- Retroperitoneal area – tamponade but hepatic vein # may bleed ++
- Glisson’s capsule intact + bleeding – expanding subcapsular haematoma
- Haematoma contained within the liver parenchyma - expansion & liquefaction
  - absorption 2 to 3 months
  - infection – abscess
  - encysted
- Arterial rupture – expansion on-going bleeding
  - pseudoaneurysm & delayed bleed # or haemobilia
  - arterio-portal fistula - peripheral: most close
    - central: may lead to portal hypertension
- Bile duct # - partial will heal if distal duct intact
  but may require intra-ductal pressure reduction for this to occur
  - larger # - on-going leak and bile ascites
  - stricture
  - biliary fistula if duct from a segment disrupted but otherwise viable
Diagnosis

- History + Physical examination
  ± tachycardia, ± hypotension, peritoneal irritation

- FAST
  better for unstable patients not stable enough for CT or as a screen for CT

- CT with contrast
  determine grade and look for active extravasation

Coley et al. J Trauma 2000
## AAST Liver Injury Grading

**American Association for the Surgery of Trauma**

<table>
<thead>
<tr>
<th>Grade</th>
<th>Description</th>
</tr>
</thead>
</table>
| I     | Hematoma: subcapsular, <10% surface area  
Laceration: capsular tear, <1 cm in parenchymal depth |
| II    | Hematoma: subcapsular, 10%–50% surface area; intraparenchymal, <10 cm in diameter  
Laceration: 1–3 cm in parenchymal depth, <10 cm in length |
| III   | Hematoma: subcapsular, >50% surface area or expanding or ruptured subcapsular hematoma with active bleeding; intraparenchymal, >10 cm or expanding or ruptured  
Laceration: >3 cm in parenchymal depth |
| IV    | Hematoma: ruptured intraparenchymal hematoma with active bleeding  
Laceration: parenchymal disruption involving 25%–75% of a hepatic lobe or one to three Couinaud segments within a single lobe |
| V     | Laceration: parenchymal disruption involving >75% of a hepatic lobe or more than three Couinaud segments within a single lobe  
Vascular: juxtahepatic venous injuries (ie, retrohepatic vena cava or central major hepatic veins) |
| VI    | Vascular: hepatic avulsion |

### Grade I
![Grade I Image]

### Grade IV
![Grade IV Image]
CT-based Injury Severity of Blunt Hepatic Trauma

<table>
<thead>
<tr>
<th>CT-based Grade</th>
<th>Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Capsular avulsion, superficial laceration(s) less than 1 cm deep, subcapsular hematoma less than 1 cm in maximum thickness, periportal blood tracking only</td>
</tr>
<tr>
<td>2</td>
<td>Laceration(s) 1–3 cm deep, central-subcapsular hematoma(s) 1–3 cm in diameter</td>
</tr>
<tr>
<td>3</td>
<td>Laceration greater than 3 cm deep, central-subcapsular hematoma(s) greater than 3 cm in diameter</td>
</tr>
<tr>
<td>4</td>
<td>Massive central-subcapsular hematoma greater than 10 cm, lobar tissue destruction (maceration) or devascularization</td>
</tr>
<tr>
<td>5</td>
<td>Bilobar tissue destruction (maceration) or devascularization</td>
</tr>
</tbody>
</table>

CT Criteria for Management of Blunt Liver Trauma: Correlation with Angiographic and Surgical Findings

Pierre A. Poletti et al. 2000: Radiology 216; 418 - 427
Liver injuries at Red Cross Children’s Hospital n=409 [32yrs] end 2013

- Isolated: 163 (40%)
- Associated: 246 (60%)
Cause of Injury

[n=409]

350 (86%) RTAs
Pedestrian 303 (87%)
Passenger 47 (13%)
Cyclist 3 (0.4%)

17 (4%) Child abuse/assault

26 (6%) Falls from/on top of

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Table 2  Comparison of mechanism of injury between isolated and multisystem trauma patients (NS not significant)

<table>
<thead>
<tr>
<th>Mechanism</th>
<th>Isolated (n = 36)</th>
<th>Multitrauma (n = 91)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Motor vehicle injury</td>
<td>15 (42%)</td>
<td>73 (80%)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Bicycle</td>
<td>9 (25%)</td>
<td>4 (4%)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Fall</td>
<td>5 (14%)</td>
<td>8 (9%)</td>
<td>NS</td>
</tr>
<tr>
<td>Horse</td>
<td>5 (14%)</td>
<td>3 (3%)</td>
<td>NS</td>
</tr>
<tr>
<td>Sport / assault</td>
<td>2 (6%)</td>
<td>1 (1%)</td>
<td>NS</td>
</tr>
<tr>
<td>NAI</td>
<td>0 (0%)</td>
<td>2 (2%)</td>
<td>NS</td>
</tr>
</tbody>
</table>

Liver Injuries

n = 409
[246 (60%) had multiple injuries]
Intra abdominal injuries

n = 191
Management outcome
\[ n = 409 \]
Mean age: 7 years (2-13)

- Non-operative management \[ 368 \ (91\%) \]
  - [31% required blood transfusion - mean 17ml/kg]

- Operative management \[ 38 \ (9\%) \]
  - [100% required blood transfusion - mean 30.4ml/kg]

- Died soon after arrival \[ 3 \]
- Died after surgery \[ 3 \ [2HI, 1 LI] \]

Mean hospital stay: 7 days (r: 4 - 49)
## APSA Guidelines

APSA guidelines for hemodynamically stable children with isolated spleen or liver injury

<table>
<thead>
<tr>
<th>CT GRADE</th>
<th>I</th>
<th>II</th>
<th>III</th>
<th>IV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Days in ICU</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>1 day</td>
</tr>
<tr>
<td>Hospital stay</td>
<td>2 days</td>
<td>3 days</td>
<td>4 days</td>
<td>5 days</td>
</tr>
<tr>
<td>Pre discharge imaging</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>Post discharge imaging</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>Activity restrictions</td>
<td>3 weeks</td>
<td>4 weeks</td>
<td>5 weeks</td>
<td>6 weeks</td>
</tr>
</tbody>
</table>

From Stylianos S, and APSA Trauma Committee: Evidence-based guidelines for resource utilization in children with isolated spleen or liver injury

*J Pediatr Surg 35:164-169, 2000*
Non-Operative Group (n=368)

- CT or liver scintigraphy [prior to 1984]
- NOM not “conservative” management
- High care or ICU
- Close monitoring of haemodynamic status
- Serial hemoglobin, electrolytes, LFT’s,
- Blood pressure, serum lactate, base excess
- Transfusion requirements  [<20ml/kg]
Non-Operative complications

- Ruptured sub-capsular haematoma  
  One delayed laparotomy  
  One treated non-operatively

- Abscesses  
  Liver  
  Pelvic  
  Sub-phrenic  
  Infected abdominal wall

- Pancreatic pseudocyst

- Biliary fistula

- Fat embolism

- Adhesive bowel obstruction
Operative Management - Surgical Techniques

• Simple Techniques [good access essential]
  – Cautery, Pringle, topical haemostatic agents, hepatotomy & suture ligation of superficial/deep vessels

• Complicated Injuries
  – Pringle to vascular exclusion & aortic clamping
  – Mesh wrapping [not used]
  – Packing
  – Hepatic artery ligation [used on 1 occasion only]
  – Atrio-caval shunting [not used]
  – Liver transplant [rare but life saving]
Surgical techniques of haemorrhage control

Pringle inflow occlusion

Pringle + hepatotomy, control and suture
Grade 2 - 3 blunt injury with a ‘blush’ of contrast requiring operation and hepatotomy to secure haemostasis

+/- 25% failure of NOM with constant blush on CT

+/- Angioembolization

11yr old blunt trauma – increasing abdominal pain, distension & liver enlargement over 24hrs

Huge sub-capsular haematoma under pressure with early necrosis of surrounding liver
CT and angio of grade IV injury with 2 areas of arterial bleeding

First bleeder coiled – note second still bleeding
Technique of peri-hepatic packing
- Restoring the liver anatomy!
Follow-up

• Imaging used for follow-up
  – Serial Ultrasound scan [long term]
  – Serial Computer Tomographyography [clinical need]
  – HIDA scan for suspected bile duct leak

• Of those who returned for follow-up
  – all showed resolution and healing of hepatic injury after 3 to 9 months depending on the severity of the injury
  – Intrahepatic vascular pedicle injury may be associated segmental atrophy
Contrast Enhanced Ultrasound [CEUS] vs CT [in the acute phase]

N Durkin et al., J Ped Surg. 2016. 51;2:289 - 292
Liver injuries in children: The role of selective non-operative management
A. Landau, A.B. van As, A. Numanoglu, A.J.W. Millar and H. Rode
Trauma Unit, Department of Pediatric Surgery, Red Cross Children’s Hospital.
Injury 2006. 37:66-71 [updated to 2013]

Management of liver injuries

Died soon after arrival 3 [severe polytrauma]
Non-operative 368
• Operative 30
• Complications 25 (8%)
• Mortality 3 [1 liver, 2 HI]
• Total 409

“Even though most patients can be treated non-operatively, the challenge
is to identify the severely injured child early, institute aggressive
resuscitation and expedite laparotomy”.

Birmingham Children’s Hospital  
West Midlands U.K.

• Tertiary / Quaternary Hepatobiliary and Transplant Centre
• Different spectrum of severity of injury + age up to 16yrs
• Fewer pedestrian injuries
• Bicycle - handle bar +
• High speed RTA with seat belt +
Liver trauma – bicycle handle bar
## Type & complications after local primary management in 15 patients referred to a tertiary centre

<table>
<thead>
<tr>
<th>Type of primary management (no. of patients)</th>
<th>Complications</th>
<th>Types of complications</th>
<th>Secondary management</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conservative – Non-operative (n=8)</td>
<td>Biliary (n=2)</td>
<td>Biliary peritonitis</td>
<td>ERCP, stenting</td>
</tr>
<tr>
<td></td>
<td>Vascular (n=2)</td>
<td>Rupture of arterial pseudo aneurysm</td>
<td>Embolization</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Arterio-portal fistula</td>
<td>Embolization</td>
</tr>
<tr>
<td>Urgent Laparotomy (n=7)</td>
<td>Biliary (n=4)</td>
<td>Bile leaks</td>
<td>Suture of duct (n=1)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Transcystic biliary drain (n=3)</td>
</tr>
</tbody>
</table>
### Biliary & vascular complications [1998-2007]

<table>
<thead>
<tr>
<th>Type of biliary complication</th>
<th>No. of Patients</th>
<th>Day diagnosed</th>
<th>Mode of diagnosis</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Biliary complications (n=13)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intra-hepatic biloma</td>
<td>3</td>
<td>2,3,4</td>
<td>Protocol TBIDA</td>
</tr>
<tr>
<td>Bile leak into peritoneum</td>
<td>2</td>
<td>2,2</td>
<td>Protocol TBIDA</td>
</tr>
<tr>
<td>Bile leak in the abdominal drain</td>
<td>4</td>
<td>3,3,5, 12,</td>
<td>Bile in drain fluid</td>
</tr>
<tr>
<td>Biliary peritonitis</td>
<td>3</td>
<td>12,22,18,</td>
<td>Abdominal aspiration (n=2), Laparotomy (n=1)</td>
</tr>
<tr>
<td>Others</td>
<td>1</td>
<td>2</td>
<td>At laparotomy</td>
</tr>
</tbody>
</table>

| **Vascular complications (n=2)** | | | |
| Intra-hepatic arterial pseudoaneurysm | 1 | 22 | Emergency angiography |
| Arterioportal fistula          | 1 | 180 | Angio-embolization & follow-up ultrasound |
11 year old female RTA
Shocked – resuscitation – CT
Intra-hepatic vascular injury
Non-perfusion of left liver lobe
Urgent laparotomy & left hepatectomy

3 year old boy RTA
Shocked – resuscitation
CT with contrast – blush
Urgent laparotomy suture of laceration in portal vein
14 yr. old – 22 days post injury, pain and malaena requiring transfusion
Ruptured hepatocellular adenoma after relatively minor trauma. Contrast-enhanced CT image shows a large heterogeneous low-attenuation mass (arrow) in the right hepatic lobe, and a loss of liver capsule integrity antero-laterally.
Missed bile duct injury
11 year old RTA, haemodynamic instability despite resuscitation – laparotomy & haemostasis
POD 4 – bile leak
Bile leaks – what options

- Drain (percutaneous) and wait
- ERCP and stent +/- sphincterotomy [biodegradable stents, BOTOX injection]
- Operative repair [op. cholangiogram]
- Cholecystectomy & trans-cystic duct tube decompression
- Roux-en-Y drain for persistent fistula
Elective TBIDA scan + drain + biliary decompression

a) Intra-hepatic biloma

Bile duct decompression and drain concept to promote healing of biliary leaks
a) Percutaneous drain & endoscopically placed stent
b) Open drain & T-tube
c) Open drain + cholecystectomy & trans-cystic tube

Transcystic, transpapillary tube (TCTPT)-
Multifenestrated feeding tube inserted through the
cystic duct into the distal common bile duct and
duodenum

Papilla splinted open to release the
positive pressure within the bile ducts

b) Bile leak into peritoneum

Cholecystectomy +
Trans cystic duct tube decompression
and drain (Feneryou B. 1987 & J. de Ville 2002)
Bile Leaks – ERCP and stent/spincterotomy

A 13yr old RTA with major left sided injury – CT shows fluid and left liver laceration
ERCP shows left duct # - treated by stent/sphincterotomy
Liver trauma
Assessment / Resuscitation

Clinically stable
+ physical signs

CEUS & Contrast CT

Clinically unstable
Hypotension, tachycardia, pallor, falling haemoglobin

Major liver trauma
Parenchymal fracture >4cmCT, Involving the hilum

TBIDA scan
Day 2-4

Intra-hepatic biloma
observe/drain

Intra peritoneal bile leak

Arterial blush sign

Laparotomy

Angiography +/- embolisation

ERCP, Stenting of ampulla

Intra peritoneal bile leak

Not-responding to resuscitation

Laparotomy, Transcystic biliary drain
Recombinant FVIIa (N7) inhibitors against FVII following cardiac surgery: paediatric non-haemorrhagic damage control surgery in the trauma in paediatric patients.

Patient A, a 20kg, seven year old male, presented to the trauma unit in June 2009 following a motor vehicle accident. He had sustained blunt abdominal trauma as well as a fractured right femur. He had unresponsive Grade 4 Haemorrhagic shock mandating an emergency laparotomy. At laparotomy he was found to have a grade 4/5 laceration to the Right Hepatic lobe. Intra-operative resuscitation with 45ml/kg of packed red cells, FFP and damage control surgical techniques: in-flow control (Pringle manoeuvre) and liver packing with abdominal swabs were instituted. rFVIIa (120 KIU) was administered in order to secure adequate haemostasis. The patient made a successful recovery after re-look laparotomy in 48hrs to remove abdominal packs.

2009, p1066-1071
4. Use of rFVIIa in Traumatic Liver Injuries in Children; R. Kulkarni et al; The Journal of Trauma number 56, June 2004, p1348-1352
Retro-hepatic IVC haemorrhage

1. Transverse incision with midline cranial extension
2. Packing of the liver and volume resuscitation with Rapid Infusion System prior to vascular isolation
3. Isolation of the intra-pericardial vena cava through a trans-diaphragmatic pericardial window
4. Control the suprarenal vena cava and porta hepatis
5. Repair of vein lacerations with vascular occlusion & continuous saline irrigation for improved visualization
Conclusions

- Contrast blush on initial CT scan is a useful indicator of ongoing haemorrhage and the need for urgent laparotomy or angiographic intervention.
- Bile duct injuries are more frequently seen in the select group of children suffering severe liver trauma.
- TBIDA scan is a sensitive investigation for bile duct injury in severe liver trauma in children.
- Adjunctive procedures such as angiography and embolization play an essential role in treating vascular injuries.
- The challenge is to identify early the severe injury requiring immediate life saving surgical intervention.
- Factor VII and packing can be life saving.