Surgical intervention for paediatric liver injuries is almost history - a 12-year cohort from a major Scandinavian trauma centre

Tomohide Koyama¹*, Jorunn Skattum¹, Peder Engelsen², Torsten Eken³, Christine Gaarder¹ and Pål Aksel Naess¹,4

Abstract

**Background:** Although nonoperative management (NOM) has become standard care, optimal treatment of liver injuries in children is still challenging since many of these patients have multiple injuries. Moreover, the role of angiography remains poorly defined, and a high index of suspicion of complications is warranted. This study reviews treatment and outcomes in children with liver injuries at a major Scandinavian trauma centre over a 12-year period.

**Methods:** Patients <17 years old with liver injury admitted to Oslo University Hospital Ullevaal during the period 2002-2013 were retrospectively reviewed. Data were compiled from the institutional trauma registry and medical records.

**Results:** A total of 66 children were included. The majority was severely injured as reflected by a median injury severity score of 20.5 (mean 22.2). NOM was attempted in 60 (90.9%) patients and was successful in 57, resulting in a NOM success rate of 95.0% [95% CI 89.3 to 100]. Only one of the three NOM failures was liver related, occurred in the early part of the study period, and consisted in operative placement of drains for bile leak. Two (3.0%) patients underwent angiographic embolization (AE). Complications occurred in 18 (27.3% [95 % CI 16.2 to 38.3]) patients. Only 2 (3.0%) patients had liver related complications, in both cases bile leak. Six (9.1%) patients underwent therapeutic laparotomy for non-liver related injuries. Two (3.0%) patients died secondary to traumatic brain injury.

**Discussion:** This single institution paediatric liver injury cohort confirms high attempted NOM and NOM success rates even in patients with high grade injuries and multiple accompanying injuries. AE can be a useful NOM adjunct in the treatment of paediatric liver injuries, but is seldom indicated. Moreover, bile leak is the most common liver-related complication and the need for liver-related surgery is very infrequent.

**Conclusion:** NOM is the treatment of choice in almost all liver injuries in children, with operative management and interventional radiology very infrequently indicated.

**Keywords:** Children, Hepatic trauma, Nonoperative management, Angiographic embolization, Traumatic bile leak

* Correspondence: t-koyama@office.nifty.jp

¹Department of Traumatology, Oslo University Hospital Ullevaal, PO Box 4950Nydalen, N-0424 Oslo, Norway

© The Author(s). 2016 Open Access This article is distributed under the terms of the Creative Commons Attribution 4.0 International License (http://creativecommons.org/licenses/by/4.0/), which permits unrestricted use, distribution, and reproduction in any medium, provided you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons license, and indicate if changes were made. The Creative Commons Public Domain Dedication waiver (http://creativecommons.org/publicdomain/zero/1.0/) applies to the data made available in this article, unless otherwise stated.
Background
Nonoperative management (NOM) has become standard care in children with isolated blunt liver injuries based on experiences from institutions in North America [1, 2]. However, the role of some interventions, such as angiographic embolization (AE), is still uncertain [3]. Furthermore, the optimal treatment of bile leaks is still a matter of uncertainty. Another problem is posed by patients with other injuries that might challenge NOM of the liver injury. Yet, there is a paucity of reports from Europe addressing contemporary treatment of paediatric liver injuries.

The aim of the present study was to review the treatment and outcomes in children with liver injuries at a major Scandinavian trauma centre over a recent 12-year period to clarify whether our treatment practice and results are in accordance with international standards.

Methods
All patients <17 years old with liver injury admitted at Oslo University Hospital Ullevaal (OUHU) from January 1st 2002 to December 31st 2013 were retrospectively identified from the institutional trauma registry. The trauma registry includes all trauma patients admitted through trauma team activation (irrespective of ISS), or with penetrating injuries proximal to elbow or knee, or with ISS ≥9 admitted to OUHU directly or via a local hospital within 24 h after injury. Transfers more than 24 h after injury are included only if the trauma team is activated. The study was approved by the Institutional Data Protection Officer.

Patients categorised as dead on arrival or who died within 30 min of arrival were excluded from further analysis, as were patients transferred from other hospitals later than 24 h after injury.

Demographic data, mechanism of injury (MOI), anatomic injury by body region (classified according to the Abbreviated Injury Scale (AIS) 98), Injury Severity Score (ISS), haemodynamic and physiological parameters on admission, admission laboratory values, diagnostic examinations, management strategies, and outcomes were compiled from the trauma registry and medical records of the patients.

As part of the study the computed tomographic (CT) scans were reviewed for liver injury severity and scored according to the Organ Injury Scale (OIS, 1994 revision) described by the American Association for the Surgery of Trauma [4].

Positive abdominal findings included: abdominal pain, signs of abdominal wall injury, peritonism, haematuria, melena or haematemeses.

Outcome data included NOM, failure of NOM (NOM-F), operative management (OM), AE as part of NOM, transfusions within the first 24 h, complications, intensive care unit (ICU) and in-hospital length of stay (LOS), and mortality.

NOM-F was defined as laparotomy performed after a period of attempted NOM. Angiography-related complications were defined as puncture site haematoma or pseudoaneurysm, intimal tears, unintentional coil migration, gallbladder necrosis, and allergic contrast reaction. Liver-related complications were defined as delayed liver haemorrhage, hepatic abscess, hepatic necrosis, bile leak, biloma, haemobilia, bilhaemia, and biliary fistulae.

To clarify whether NOM is achievable even in patients with severe liver injuries the subgroups of patients with high grade injuries (OIS grade IV-V) and patients with OIS grade I-III injuries were compared.

Categorical variables were presented as observed frequency with percentage, with addition of 95% confidence intervals (CI) for the overall NOM success and complication rates, and compared by Chi square or Fisher exact tests as deemed appropriate. Continuous variables were presented as median with inter quartile range (IQR), and subjected to the Mann-Whitney U test. All p values reported are two-sided, and p values <0.05 were considered to indicate statistical significance. Statistical analysis was performed using the IBM SPSS Statistics version 22 (International Business Machines Corp., New York, USA).

Results
A total of 72 paediatric patients with liver injuries were admitted during the study period. Six patients were excluded from further analysis based on the aforementioned criteria.

The MOI was blunt in 64 (97.0%) of the 66 included cases secondary to (only categories with more than one patient included): falls (22.7%, n = 15), motor vehicle crashes (MVC) (19.7%, n = 13), bicycle accidents (15.2%, n = 10), ski or snowboard activities (12.1%, n = 8), pedestrian accidents (10.6%, n = 7), and all-terrain vehicle (ATV) crashes (4.5%, n = 3).

Of the 66 included patients, nine (13.6%) had OIS grade I injury, 23 (34.8%) had grade II injury, 17 (25.8%) had grade III injury, 16 (24.2%) had grade IV injury, and one (1.5%) had a grade V injury.

Patient characteristics and outcome data for the total cohort and stratified by liver injury severity are presented in Table 1. Most patients were severely injured as reflected by a median ISS of 20.5 (10; 33), time spent in ICU 2 (1; 5) days, and overall LOS 7 (5; 11.3) days. A total of 58 (87.9%) patients had combined injuries: 15 patients had head injuries, 19 had facial injuries, five had spinal injuries, 35 had chest injuries, 27 had other abdominal injuries, and 21 had injuries to the pelvis or extremities in addition to the liver injury.

As expected, children with grade IV-V injuries had higher median ISS, aspartate transaminase (AST) levels,
and alanine transaminase (ALT) levels than patients with grade I-III injuries.

NOM was attempted in 60 (90.9%) patients and was completed in 57 resulting in a NOM success rate of 95.0% [95% CI 89.3 to 100]. All NOM-F occurred in the first two years of the study period, and only one was liver related. Two NOM-F were not liver related. In both cases, laparotomy was performed for associated abdominal injuries, one resulting in splenectomy and the other in distal pancreatectomy.

Only two patients underwent angiography due to their liver injuries. Both had been subjected to a handle bar injury and were transferred from a local hospital after CT scan showed high grade liver injury. They both showed clinical signs of bleeding within the first 24 h after admission and underwent angiography followed by successful selective AE of branches of the right hepatic artery.

Six (9.1%) children with liver injury underwent OM. Four patients had non-liver related therapeutic laparotomy performed based on clinical and/or radiological findings: three had repair of hollow viscus injuries (HVI) and one had a repair of a diaphragmatic rupture. Two children underwent planned second look surgery with abdominal closure after damage control surgery in local hospitals prior to transfer.

Complications occurred in 18 (27.3% [95% CI 16.2 to 38.3]) patients. Only two patients had liver related complications, in both cases bile leak. The first patient with bile leak was treated with percutaneous drainage on day 11. The leak gradually decreased and the drain could be successfully removed after 11 days. The second patient was one of the NOM-F previously mentioned. He was diagnosed with a bile leak on post injury day 6 that was drained percutaneously followed by operative placement of perihepatic drains which were subsequently removed with no further complications. There was no need for endoscopic interventions.

Two (3.0%) patients died secondary to severe traumatic brain injury (TBI).

**Discussion**

This single institution paediatric liver injury cohort demonstrates high attempted NOM and NOM success rates even in patients with high grade injuries and multiple accompanying injuries. AE can be a useful NOM adjunct in the treatment of paediatric liver injuries, but is seldom indicated. Moreover, bile leak is the most common liver-related complication and the need for liver-related surgery and endoscopic interventions is very infrequent.

Most of the patients (87.9%) had multiple injuries as reflected in the high median ISS of 20.5, which is slightly

### Table 1 Patient demographics and outcomes for the total cohort and stratified by liver injury severity

|                      | All (n = 66) | OIS I-III (n = 49) | OIS IV-V (n = 17) | p value |
|----------------------|-------------|-------------------|------------------|--------|
| **Age**              |             |                   |                  |        |
|                      | 10.5 (6.8; 14.1) | 10.9 (6.8; 14.2) | 10.0 (7.1; 13.1) | 0.67   |
| **Male gender**      | 43 (65.2)   | 32 (65.3)         | 11 (64.7)        | 0.96   |
| **Blunt injury**     | 64 (97.0)   | 47 (95.9)         | 17 (100)         | 1.00   |
| **ISS**              | 20.5 (10.0; 33.0) | 17.0 (9.0; 28.0) | 25.0 (17.0; 34.0) | 0.02   |
| **GCS**              | 15.0 (14.0; 15.0) | 15.0 (14.0; 15.0) | 15.0 (15.0; 15.0) | 0.16   |
| **Base excess**a     | –2.1 (–4.9; –1.1) | –2.4 (–4.7; –0.9) | –2.0 (–5.3; –1.4) | 0.96   |
| **Lactate**b         | 2.2 (1.3; 2.9) | 2.3 (1.3; 2.9)    | 1.8 (1.4; 2.9)   | 0.55   |
| **Aspartate transaminase**c | 302.5 (161.3; 521.0) | 261.0 (145.0; 357.0) | 618.0 (416.5; 969.0) | <0.01   |
| **Alanine transaminase**d | 220.0 (120.0; 390.0) | 189.5 (110.8; 266.5) | 461.0 (355.0; 723.0) | <0.01   |
| **Positive abdominal findings** | 45 (68.2)   | 29 (59.2)         | 16 (94.1)        | 0.01   |
| **Attempted NOM**    | 60 (90.9)   | 45 (91.8)         | 15 (88.2)        | 0.64   |
| **Angiographic embolization** | 2 (3.0)   | 0 (0.0)           | 2 (11.8)         | 0.06   |
| **Patients transfused** | 14 (21.2)  | 10 (20.4)         | 4 (23.5)         | 0.74   |
| **ICU LOS**          | 2.0 (1.0; 5.0) | 2.0 (1.0; 5.0)    | 2.0 (1.5; 7.0)   | 0.84   |
| **In-hospital LOS**  | 7.0 (5.0; 11.3) | 6.0 (5.0; 11.5)   | 7.0 (6.0; 13.0)  | 0.18   |
| **Mortality**        | 2 (3.0)     | 1 (2.0)           | 1 (5.9)          | 0.45   |

Values are given as median (first and third quartiles) or n (%) as appropriate
OIS organ injury scale, ISS injury severity score, GCS Glasgow coma scale, NOM nonoperative management, ICU intensive care unit, LOS length of stay
*aData from 50 patients
*bData from 36 patients
*cData from 62 patients
*dData from 63 patients
higher than other studies [5–7]. This is also reflected in days spent in the ICU and overall LOS. Although the overall mortality of 3.0% in our cohort was lower than reported in the aforementioned studies, this probably reflects different exclusion criteria and does not allow any speculations about differences in the quality of care. The main cause of death was TBI as in most paediatric trauma cohorts [5–11].

Although many studies report MVCs to be the most common MOI [6, 11–14], fall was the leading MOI in our population. Ski and snowboard activities caused 12.1% of the injuries, probably reflecting the popularity of winter sports in Norway. ATV-related injuries in children have received much attention [15–17], in our cohort three (4.5%) patients were involved in ATV crashes.

Elevated serum levels of AST and ALT seem to be a reliable indicator of liver injury in children within the first hours after trauma [18–20]. In accordance with this, both AST and ALT levels were markedly increased and correlated to OIS-grading (Table 1). Children with grade IV-V injuries had significantly higher levels of AST and ALT on admission compared to children with grade I-III injuries.

NOM of hepatic injuries is the standard of care in haemodynamically normalised paediatric patients [1, 2]. Such patients tolerate diagnostic work-up with CT scan. Unless other injuries that mandate laparotomy are verified (e.g., free intraabdominal air indicating hollow viscus perforation), NOM of the liver injury is attempted. In spite of a slightly higher ISS in this study, the success rate of NOM was high at 95.0%, which is in accordance with other published studies [6, 10, 11, 21].

Reimaging of the liver injury is only performed on clinical suspicion of complications, e.g., suspected bleeding or bile leak. In patients with isolated liver injuries the American Pediatric Surgical Association guidelines are followed [1]. According to these guidelines routine ICU admission for 24 h is reserved for patients with high grade (≥ grade IV) injuries only and proposed hospital stay is one day longer than OIS injury grade. We do not practice mandatory bed rest. In the ward recording of blood pressure and pulse rate is done every fourth hour the first 24 h and then three times/24 h until discharge. Activity restriction after discharge is two weeks longer than OIS injury grade and return to full-contact, competitive sports should be individualized [1].

Despite the high NOM success rates, there is still concern about of missing HVIs when NOM is standard care. However, the reported overall rates of HVI in children with blunt abdominal trauma are as low as 0.8–3.2% [22–24]. In the present study, the three (4.5%) patients with suspected HVIs based on clinical and radiological findings all underwent primary OM and the diagnosis was confirmed perioperatively.

The existing literature on AE as an adjunct treatment to paediatric liver injuries is limited to recent case series [25–27]. In our cohort, only two (3.0%) patients underwent AE, but the procedure was therapeutic in both cases and further transfusions and more invasive surgical procedures were thus avoided. In our opinion AE as an adjunct to NOM should be considered only in patients with a CT verified liver injury with extravasation, and who develop clinical signs of bleeding.

Liver related complications are rare (0.0–8.0%) and the main cause is bile leak, as reported by several authors [5, 11, 28, 29]. The development of new symptoms, including increasing abdominal pain, distention, nausea, and vomiting will prompt suspicion in the majority of cases [29]. In our cohort, two (3.0%) patients underwent drainage procedures due to bile leak. In the first year of the study period one patient underwent operative placement of perihepatic drains due to ongoing bile leak after removal of percutaneous drains. In the later part of the period the second patient with bile leak underwent curative percutaneous drainage. Kulaylat et al. presented the largest single-institution series with bile leaks from blunt liver injury in children in 2014 [29]. Based on their successful experience with 11 patients they recommended percutaneous drainage combined with endoscopic retrograde cholangiopancreatography (ERCP) with sphincterotomy and/or biliary stenting. Whether ERCP related procedures increase the success rate of percutaneous drainage cannot be established from that study. ERCP is an invasive procedure with associated complications, and our experience with adult and paediatric liver injuries is that bile leaks stop eventually spontaneously, without the need for ERCP.

This study has limitations in addition to its retrospective nature. It is a single-institution study describing a limited number of children with liver injuries over a 12-year period. However, the reported data clearly demonstrate high attempted NOM and NOM success rates in a cohort of severely injured patients.

**Conclusion**

This single institution paediatric liver injury cohort confirms high attempted NOM and NOM success rates even in patients with high grade injuries and multiple accompanying injuries. AE can be a useful NOM adjunct in the treatment of paediatric liver injuries, but is seldom indicated and should be considered only in patients with a CT verified liver injury with extravasation, and who develop clinical signs of bleeding. Moreover, bile leak is the most common liver-related complication, should be treated with percutaneous drainage, and the need for liver-related surgery is very infrequent.
Abbreviations
AE: Angiographic embolization; AIS: Abbreviated injury scale; ALT: Alanine transaminase; AST: Aspartate transaminase; ATV: All-terrain vehicle;
CI: Confidence interval; CT: Computed tomography; HVI: Hollow viscus injury;
ICU: Intensive care unit; ISS: Injury severity score; LOS: Length of stay;
MVC: Motor vehicle crash; NOM: Nonoperative management; NOM-F: Failure of nonoperative management; OIS: Organ injury scale;
OM: Operative management; OLUHU: Oslo University hospital Ullevaal; TBI: Traumatic brain injury

Acknowledgements
Not applicable.

Funding
The authors declare that they have no funding.

Availability of data and materials
The approval from the Institutional Data Protection Officer did not include free sharing of data.

Authors’ contributions
TK, JS, CG, PAN conceived the study. TK, JS, PE, TE, PAN collected the data. TK, PAN analyzed the data. TK, CG, PAN wrote the manuscript, which JS, PE, TE critically revised, and all authors approved the final version.

Competing interests
The authors declare that they have no competing interests.

Consent for publication
Not applicable.

Ethics approval and consent to participate
The study was approved by the Institutional Data Protection Officer.

Author details
1Department of Traumatology, Oslo University Hospital Ullevaal, PO Box 4950Nydalen, N-0424 Oslo, Norway. 2School of Medicine, University of Oslo, Oslo, Norway. 3Department of Anesthesiology, Oslo University Hospital Ullevaal, Oslo, Norway. 4University of Oslo, Oslo, Norway.

Received: 27 May 2016 Accepted: 15 November 2016
Published online: 29 November 2016

References
1. Stylianos S. Compliance with evidence-based guidelines in children with isolated spleen or liver injury: a prospective study. J Pediatr Surg. 2002;37(9):153–6.
2. Richardson JD. Changes in the management of injuries to the liver and spleen. J Am Coll Surg. 2005;200(SI):648–69.
3. Gain BA. Intra-abdominal solid organ injury in children: diagnosis and management. J Trauma. 2007;62(7 Suppl 1):S315–9.
4. Moore EE, Cogbill TH, Jurkovich GJ, Shackford SR, Malangoni MA, Champion HR. Organ injury scaling: spleen and liver (1994 revision). J Trauma. 1994;36(3):324–43.
5. Miller K, Kou D, Sivit C, Stallion A, Dudgeon DL, Grisoni ER. Pediatric hepatic trauma: does clinical course support intensive care unit stay? J Pediatr Surg. 1998;33(10):1459–62.
6. Deluca JA, Maxwell DR, Flaherty SK, Prigozen JM, Scragg ME, Stone PA. Injuries associated with pediatric liver trauma. Am Surg. 2007;73(1):37–41.
7. Nellenstein D, Porte RL, van Zureun W, ten Duis HJ, Hulscher JB. Paediatric blunt liver trauma in a Dutch level 1 trauma center. Eur J Pediatr Surg. 2009;19(6):358–61.
8. Kumar R, Holland AJ, Shi E, Cass DT. Isolated and multisystem hepatic trauma in children: the true role of non-operative management. Pediatr Surg Int. 2002;18(2–3):98–103.
9. Paddock HN, Tepas 3rd JJ, Ramenofsky ML, Vane DW, Diccala C. Management of blunt pediatric hepatic and splenic injury: similar process, different outcome. Am Surg. 2004;70(12):1068–72.
10. Giss SR, Dobrilovic N, Brown RL, Garcia VF. Complications of nonoperative management of pediatric blunt hepatic injury: Diagnosis, management, and outcomes. J Trauma. 2006;61(2):334–9.
11. Landa A, van As AB, Rumangou A, Millar AJ, Rode H. Liver injuries in children: the role of selective non-operative management. Injury. 2006;37(1):66–71.
12. Leone J Jr, Hammond JS. Nonoperative management of pediatric blunt hepatic trauma. Am J Surg. 2001;182(2):138–42.
13. Pryor JP, Stafford PW, Nance ML. Severe blunt hepatic trauma in children. J Pediatr Surg. 2001;36(7):974–9.
14. Hackam DJ, Potoka D, Meza M, Pollock A, Gardner M, Abrams P, et al. Utility of radiographic hepatic injury grade in predicting outcome for children after blunt abdominal trauma. J Pediatr Surg. 2002;37(3):386–9.
15. Campbell BT, Kellher MM, Borrup K, Consi J, Saleheen H, Boude MO, et al. All-terrain vehicle riding among youth: how do they fair? J Pediatr Surg. 2010;45(5):925–9.
16. Shults RA, West BA, Rudd RA, Helmkamp JC. All-terrain vehicle-related nonfatal injuries among young riders in the United States, 2001–2010. Pediatrics. 2013;132(2):282–9.
17. Mazotas I, Toal M, Borrup K, Saleheen H, Hester AL, Copeland D, et al. A prospective, multi-institutional study of pediatric all-terrain vehicle crashes. J Trauma Acute Care Surg. 2014;77(1):103–8.
18. Oldham KT, Guice KS, Kaufman RA, Martin LW, Noseworthy J. Blunt hepatic injury and elevated hepatic enzymes: a clinical correlation in children. J Pediatr Surg. 1984;19(4):457–61.
19. Svozil A, Hirsch K. Blunt abdominal trauma in children: risks of nonoperative treatment. J Pediatr Surg. 1997;32(8):1169–74.
20. Ritchie AH, Williscoat DM. Elevated liver enzymes as a predictor of liver injury in stable blunt abdominal trauma patients: case report and systematic review of the literature. Can J Rural Med. 2006;11(4):283–8.
21. Amroch D, Schiavon G, Carmignola G, Zoppello F, Marzaro M, Bertoni F, et al. Isolated blunt liver trauma: is nonoperative treatment justified? J Pediatr Surg. 1992;27(4):466–8.
22. Allen GS, Moore FA, Cox Jr CS, Wilson JT, Cohn JM, Duke JH. Hollow visceral injury and elevated hepatic enzymes: a clinical correlation in children. J Pediatr Surg. 1998;34(1):69–75.
23. Nance ML, Keller MS, Stafford PW. Predicting hollow visceral injury in the pediatric blunt trauma patient with solid visceral injury. J Pediatr Surg. 2000;35(9):1300–3.
24. Holmes JW, Webe DJ, Tataria M, Mattix KD, Mooney DP, Scaife ER, et al. The failure of nonoperative management in pediatric solid organ injury: a multi-institutional experience. J Trauma. 2005;59(6):139–43.
25. Klankhooy A, Sartorelli KH, Vane DW, Bhave AD. Angiographic embolization is safe and effective therapy for blunt abdominal solid organ injury in children. J Trauma. 2010;68(3):526–31.
26. Onig CC, Toh L, Lo RH, Yap TL, Narasimhan K. Primary hepatic artery embolization in pediatric blunt hepatic trauma. J Pediatr Surg. 2012;47(12):2216–20.
27. Falkon SC, Coker MT, Hernandez IA, Rimpalwar SA, Minifie PK, Fishman DS, et al. Traumatic hepatic artery laceration managed by transarterial embolization in a pediatric patient. J Pediatr Surg. 2013;48(6):E9–12.
28. Gross M, Lynch F, Canty Sr T, Peterson B, Spear R. Management of pediatric liver injuries: a 13-year experience at a pediatric trauma center. J Pediatr Surg. 1999;34(10):811–6.
29. Kulyaat AN, Stokes AL, Engbrecht BW, McIntyre JS, Ruzicdillo SE, Cilley RE. Traumatic bile leaks from blunt liver injury in children: a multidisciplinary and minimally invasive approach to management. J Pediatr Surg. 2014;49(3):424–7.

Submit your next manuscript to BioMed Central and we will help you at every step:
• We accept pre-submission inquiries
• Our selector tool helps you to find the most relevant journal
• We provide round the clock customer support
• Convenient online submission
• Thorough peer review
• Inclusion in PubMed and all major indexing services
• Maximum visibility for your research

Submit your manuscript at www.biomedcentral.com/submit