Original article

Concomitant injuries are an important determinant of outcome of high-grade blunt hepatic trauma

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Background: Little is known about the clinical importance of concomitant injuries in polytraumatized patients with high-grade blunt liver injury. A retrospective single-centre study was performed to investigate the safety of non-operative management of liver injury and the impact of concomitant intra- and extra-abdominal injuries on clinical outcome.

Methods: Some 183 patients with blunt liver injury were admitted to Berne University Hospital, Switzerland, between January 2000 and December 2006. Grade 3–5 injuries were considered to be high grade.

Results: Immediate laparotomy was required by 35 patients (19·1 per cent), owing to extrahepatic intra-abdominal injury (splenic and vascular injuries, perforations) in 21 cases. The mortality rate was 16·9 per cent; 22 of the 31 deaths were due to concomitant lesions. Of 81 patients with high-grade liver injury, 63 (78 per cent) were managed without surgery; liver-related and extra-abdominal complication rates in these patients were 11 and 17 per cent respectively. Grades 4 and 5 liver injury were associated with hepatic-related and extra-abdominal complications.

Conclusion: Concomitant injuries are a major determinant of outcome in patients with blunt hepatic injury and should be given high priority by trauma surgeons. An algorithm for the management of blunt liver injury is proposed.

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Introduction

The current approach to patients with blunt liver injury favours non-operative management of the injury, including endovascular artery occlusion[1,2]. Numerous studies over the past two decades have confirmed the feasibility of this approach in up to 95 per cent of haemodynamically stable patients with blunt liver injury[2]. To improve the outcome of patients with hepatic injury, it is necessary to determine the overall morbidity and mortality of patients with blunt liver injury managed conservatively.

Purely hepatic-related complication rates are low in most series of blunt liver injury, ranging from 0 to 7 per cent, but they increase with increasing severity of the lesion[2–5]. However, as the majority of patients in these studies had low-grade liver injuries, the findings cannot be extrapolated to patients with high-grade lesions, for whom conservative management may not be safe or feasible. With non-operative management, hepatic-related complication rates in patients with high-grade liver injury are 11–13 per cent[6,7], and can be predicted by the grade of liver injury and the volume of packed red blood cells transfused at 24 h postinjury[5]. Currently, there are no data available concerning the impact of concomitant intra- and extra-abdominal lesions on complications associated with a non-operative approach to blunt liver injury, although up to 75 per cent of patients with liver injury have such collateral lesions[8]. These injuries vary in surgical importance, but severe complications and non-specific laparotomies (independent of the liver injury) must be expected in a significant number of patients; non-specific laparotomy has been described in up to 20 per cent of patients with hepatic trauma[9,10].

Over the past decade, the overall mortality rate for polytraumatized patients with liver injury has remained constant at 10–15 per cent[9,11,12]. Several studies in

patients with liver injury have suggested that early deaths are due to uncontrolled bleeding from associated intra- and extra-abdominal injuries; furthermore, most late deaths result from collateral head injuries and sepsis with multiorgan failure[8,13–16]. However, there are currently no detailed data on the occurrence of extra-abdominal complications after conservative management of patients with high-grade liver injuries and multiple trauma.

A retrospective study involving 183 patients with blunt hepatic injury was performed to investigate the following hypotheses: that non-operative management can be achieved safely in patients with high-grade liver injury; that the management of patients with hepatic injury and other traumas mainly comprises the treatment of concomitant injuries and associated complications; and that, in the majority of patients, the cause of death is not related to the liver injury.

Methods

Patients with blunt liver injury presenting to Berne University Hospital, Switzerland, between January 2000 and December 2006 were included in the study; this hospital is a level I trauma centre treating about 300 patients with multiple injuries every year[17].

All charts, including surgery and autopsy reports, were reviewed retrospectively. Data included age, sex and mechanism of injury; injury patterns were defined by the Abbreviated Injury Score (AIS) and Injury Severity Score (ISS)[18]. The grade of the hepatic injury was determined separately by an experienced radiologist and two experienced hepatobiliary surgeons; in cases where the rating differed, a consensus was reached. Grading was based on contrast-enhanced computed tomography (CT) (Siemens® Somatom Sensation 16 and Somatom Plus Volume Zoom; Siemens, Munich, Germany) or laparotomy findings, according to the American Association for the Surgery of Trauma Organ Injury Scale for hepatic injuries[19,20]. In the present study, grades 3–5 were considered to be high-grade injuries[21]. Other data included the number and types of surgical procedures, hepatic-related and overall complications, and cause of death. The study was approved by the institutional ethical committee; registration number NCT00694499 (http://www.clinicaltrials.gov).

All patients were managed and resuscitated according to Advanced Trauma Life Support (ATLS®) principles[22]. *Fig. 1* shows the algorithm used for patients with blunt abdominal trauma. On arrival at the emergency department, patients underwent focused abdominal sonography for trauma (FAST) and analysis of haemoglobin levels. In patients who were haemodynamically stable, abdominal contrast-enhanced CT was performed and, if an arterial contrast blush from the liver laceration was observed, early angiography and embolization was carried out; this procedure required haemodynamic stability or at least a response to fluid resuscitation. Conservative treatment was attempted initially in all patients who were haemodynamically stable and had no arterial blush, independent of the grade of liver injury. In patients with persistent haemodynamic instability in combination with free fluid in all abdominal quadrants (detected by FAST) and decreasing systemic haemoglobin levels with no response to fluid resuscitation, an immediate laparotomy with no further abdominal CT was performed in an attempt to control the damage. This approach was also adopted in patients who were initially stable, but then deteriorated. These haemodynamically unstable patients were managed using a multidisciplinary step-by-step approach that included liver packing and, if necessary, direct repair of hepatic veins or the retrohepatic caval vein. When indicated, multiple staged procedures were performed subsequently, including non-anatomic hepatic debridement with repair of biliary vessels. All surgical interventions were performed by experienced hepatobiliary surgeons.

Biliary leaks were treated with endoscopic retrograde cholangiopancreatography (ERCP) or percutaneous transhepatic cholangio-drainage and stenting. Hepatic and/or intra-abdominal abscesses or accumulations were managed

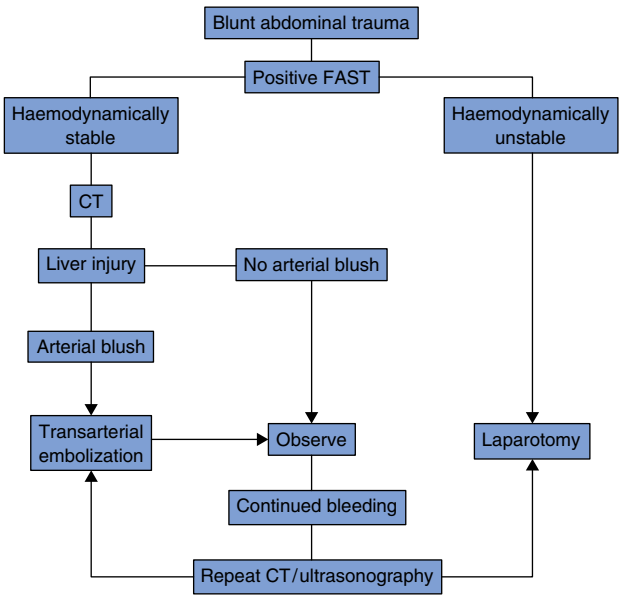

Fig. 1 Algorithm for the management of blunt abdominal trauma. FAST, focused abdominal sonography for trauma; CT, computed tomography

by CT-guided or surgical drainage. In case of surgery, patients received perioperative systemic antibiotics.

Statistical analysis

Statistical calculations were performed using SigmaStat® 1·0 (Jandel Scientific, Erkrath, Germany). Means were compared with Student's *t* test, and proportions with the χ^2 test and Fisher's exact test. $P < 0{\cdot}050$ was considered statistically significant.

Results

A total of 183 patients (123 men and 60 women) with blunt liver injury were identified; their mean(s.d.) age was 37·7(18·6) years. The mechanisms of blunt injury included 93 motor vehicle accidents, 31 falls, 23 pedestrian accidents and 36 other injuries. The mean(s.d.) ISS of patients treated surgically or without operation was 31·3(11·1) and 26·8(12·7) respectively ($P = 0{\cdot}057$, Student's *t* test).

Safety of the non-operative approach in high-grade liver injury

Of the 81 patients with grade 3–5 injury, 63 (78 per cent) were managed without surgery. All were haemodynamically stable on arrival in the emergency department. *Table 1* gives an overview of the morbidity and mortality rates (liver-related and other) observed for low- and high-grade liver injury. Overall, seven (11 per cent) of 63 patients with high-grade injury treated conservatively developed 11 liver-related complications, including bilioma ($n = 5$), haematoma ($n = 4$), abscess formation ($n = 1$) and abdominal compartment syndrome ($n = 1$). In nine cases these complications required intervention (laparotomy in three patients); other treatment strategies included ERCP, CT-guided drainage of liver abscesses and haematomas, or a conservative approach. No episodes of delayed bleeding occurred. The median time between the accident and the development of liver-related complications was 21 (range 2–45) days. Treatment was always started on the day of diagnosis.

For patients treated without surgery, liver-related complications developed in two of 39 with grade 3 liver injury, in three of 18 with grade 4 injury, and in two of six with grade 5 injury. Patients with grade 4 or 5 injury developed liver-related complications significantly more often than those with grade 1–3 injury ($P < 0{\cdot}001$, χ^2 test).

The mean(s.d.) ISS of the seven patients with high-grade hepatic injury and liver-related complications was 33·3(9·7), compared with 22·6(9·4) in the remaining 56 patients without liver-related complications ($P < 0{\cdot}001$, Student's *t* test).

There were 17 other (extra-abdominal) complications in 11 (17 per cent) of 63 patients with high-grade liver injury treated without surgery (*Tables 1* and *2*). Patients with low-grade injury had an extra-abdominal morbidity rate of 8 per cent (seven of 85) (*Table 1*). Patients with grades 4 and 5 injury developed extra-abdominal complications significantly more often than those with grade 3 injury ($P = 0{\cdot}015$, Fisher's exact test).

Overall, significantly more patients had extra-abdominal than liver-related complications (15 of 183 *versus* 29 of 183 respectively; $P = 0{\cdot}024$, χ^2 test).

Impact of concomitant damage on morbidity

Overall, 94 (51·4 per cent) of the 183 patients had a total of 140 extrahepatic abdominal lesions, with a mean(s.d.) AIS of 2·5(0·8) (*Tables 3* and *4*). Seventy-three (78 per cent) of these patients with collateral abdominal injuries were treated conservatively.

Table 1 Overview of mortality and morbidity rates of patients with liver injury

	No. of patients	Mortality		Morbidity	
		Liver-related	Other	Liver-related	Other
High-grade injury ($n = 81$)					
Non-operative management	63	2 (3)	0 (0)	7 (11)	11 (17)
Emergency laparotomy	18	7 (39)	0 (0)	7 (39)	5 (28)
Low-grade injury ($n = 102$)					
Non-operative management	85	0 (0)	17 (20)	0 (0)	7 (8)
Emergency laparotomy	17	0 (0)	5 (29)	1 (6)	6 (35)
Total ($n = 183$)					
Non-operative management	148	2 (1·4)	17 (11·5)	7 (4·7)	18 (12·2)
Emergency laparotomy	35	7 (20)	5 (14)	8 (23)	11 (31)

Values in parentheses are percentages.

Table 2 Extra-abdominal complications in patients with liver injury treated conservatively

Grade of liver injury	No. of patients*	Extra-abdominal complications
1	6 of 56 (11)	Pneumonia (4), pulmonary embolism (1), wound infection (1), SIRS (2)
2	1 of 29 (3)	Pneumonia (1)
3	3 of 39 (8)	Pneumonia (1), pulmonary embolism (1), heart failure (2), endocarditis (1), SIRS (2), MOF (1)
4	7 of 18 (39)	Pneumonia (3), heart failure (1), respiratory failure (1), SIRS (1), post-traumatic generalized epilepsy (1)
5	1 of 6 (17)	Sepsis (1), renal insufficiency (1)
Overall	18 of 148 (12·2)	

Some patients had more than one complication. *Values in parentheses are percentages. SIRS, systemic inflammatory response syndrome; MOF, multiorgan failure.

Table 3 Associated injuries and corresponding Abbreviated Injury Score in 183 patients with liver injury

Injured organ	No. of patients	Mean(s.d.) AIS
Head	102 (55·7)	2·6(0·6)
Chest	148 (80·9)	3·3(0·8)
Abdominal (other than liver)	94 (51·4)	2·5(0·8)
Bone and joint (spinal, pelvic and limb)	121 (66·1)	2·5(0·9)

Values in parentheses are percentages unless indicated otherwise. AIS, Abbreviated Injury Score.

Table 4 Extrahepatic abdominal injuries in patients with liver injury

	No. of patients
Splenic injury	50
Renal injury	45
Hollow viscus injury (avulsion of the mesentery, contusion, perforation)	15
Diaphragmatic rupture	10
Pancreatic injury	9
Vascular injury	8
Other	3
Total	140

Thirty-five patients (19·1 per cent) required an immediate laparotomy (*Table 1*), for abdominal collateral injuries in 21 cases. *Table 5* shows the indications for laparotomy in relation to the grade of liver injury. In patients with liver, splenic or vascular lesions, haemodynamic instability resulting from severe intra-abdominal bleeding was always the indication for surgery.

Fourteen of these 35 surgical procedures were due solely to the hepatic injury (*Table 5*), and included liver packing in eight patients with four direct attempts to repair the hepatic or caval veins (two were followed by secondary or tertiary liver debridement and biliary vessel repair; six patients died early from exsanguination), four primarily non-anatomic liver debridements, and two parenchymal liver sutures. Four of these 14 patients also required a splenectomy owing to concomitant severe (grade 3–5) splenic laceration. One patient required repositioning of a small bowel volvulus in addition to the hepatic repair.

Table 5 Indications for 35 emergency laparotomies in relation to the grade of liver injury

Grade of liver injury	Liver lesion	Splenic lesion	Vascular lesion	Hollow viscus perforation
1 or 2	0	10	5	2
3	6	1	2	1
4 or 5	8	0	0	0
Total	14	11	7	3

The overall ISS was significantly higher in patients with than in those without abdominal complications (mean(s.d.) 29·0 (9·3) *versus* 27·6 (12·6) respectively; $P < 0·001$, Student's *t* test).

Impact of concomitant damage on mortality

The cohort mortality rate was 16·9 per cent (31 of 183 patients). The mortality rate for patients with low- and high-grade liver injury was 21·6 per cent (22 of 102) and 11 per cent (nine of 81) respectively ($P = 0·094$, χ^2 test). Mean(s.d.) ISS for survivors and non-survivors was 24·7(11·4) and 40·2(9·8) respectively ($P < 0·001$, Student's *t* test). Overall, 18 patients died early from exsanguination as a result of the liver injury or concomitant intra- and extra-abdominal injuries (*Table 6*).

The overall mortality rate associated solely with liver injury was 4·9 per cent (nine of 183), and was always related to high-grade injury (*Tables 1* and *6*). Seven of these patients died from exsanguination during or immediately after emergency laparotomy, of whom five required a further emergency thoracotomy to control pulmonary bleeding (one patient), to cross-clamp the thoracic aorta (one) or for open-chest cardiopulmonary resuscitation (three). In four patients, deep liver lacerations with involvement of central liver veins or the caval vein caused early death by exsanguination.

Table 6 Overview of all causes of death and Injury Severity Scores

Cause of death	No. of patients	Mean(s.d.) ISS
Exsanguination by collateral damage	10	35·9(7·1)
Abdominal vascular lesion	5	
Splenic and renal lesion	2	
Pulmonary laceration	2	
Cardiac rupture	1	
Liver-related death	9*	41·3(6·8)
Exsanguination	8	
Sepsis/MOF	1	
Delayed complication	12	40·0(10·1)
Severe cerebral oedema	7	
Fatal pulmonary embolism	4	
Sepsis/MOF	1	

*All patients had grade 3–5 liver injury. ISS, Injury Severity Score; MOF, multiorgan failure.

The remaining 22 deaths (12·0 per cent of the 183 patients) were the result of severe concomitant lesions in patients with grade 1 or 2 liver injury. Thus, significantly more deaths were caused by collateral damage than by the hepatic injury ($P = 0{\cdot}002$, χ^2 test). Ten patients died early from exsanguination resulting from extrahepatic causes, and 12 died later (*Table 6*).

Discussion

Non-operative management of blunt hepatic trauma is the current standard of care in haemodynamically stable patients, including those with high-grade liver injury[3,23–25]. However, liver-related morbidity in patients with high-grade hepatic injury treated without surgery has been reported in only a few studies, with rates ranging between 11 and 13 per cent[6,7], similar to the rate of 11 per cent (seven of 63 patients) in the present study. Nine interventions were required to manage these seven liver-related complications, which in a third of the patients required laparotomy. In a retrospective multicentre study, Kozar and colleagues[6] reported a similar rate (34 per cent) for laparotomy in so-called failed non-operative management of liver injury. In their study, liver-related complications were related to grade 4 and 5 hepatic injury and the 24-h postinjury packed red blood cell requirement[6]. A similar association between grade 4–5 injury and the development of abdominal complications was found in the present study. The classification of injury severity used was analogous to that described by Moore *et al.*[19,20], and appeared to correlate with morbidity. The present findings suggest a cut-off between grade 3 and 4 liver injury for the development of serious complications, with grade 3 more similar to a low-grade injury.

The observation that the overall ISS was significantly higher in patients with than in those without abdominal complications was not surprising, because the grade of liver injury can influence the overall ISS.

No detailed data are currently available regarding other (extra-abdominal) complications during conservative treatment of hepatic injury. In the present study non-operative treatment was associated with an extra-abdominal morbidity rate of 17 per cent for high-grade and 8 per cent for low-grade liver injury. Grades 4 and 5 were significantly associated with extra-abdominal complications, compared with the rate for grade 3 injury; again, the cut-off was between grades 3 and 4.

Significantly more patients had extra-abdominal than liver-related complications. A large proportion (12 of 26) of the extra-abdominal complications consisted of pulmonary disorders, probably due to abdominal pain-related respiratory insufficiency; others were related directly to additional thoracic injuries. Some 80·9 per cent (148 of 183) of patients had accompanying chest injuries, with a mean(s.d.) AIS of 3·3(0·8), illustrating the severity of the pattern of injury in patients with hepatic injury and concomitant trauma. Thus, when investigating the safety of non-operative management of liver injury, extra-abdominal morbidity should always be included.

In this study, approximately one in five patients with blunt liver injury required an emergency laparotomy; 21 of these 35 interventions were due to concomitant life-threatening intra-abdominal damage (non-specific laparotomies). Few studies have investigated non-specific laparotomies in patients with liver injury; rates of 10–20 per cent have been reported[9]. The present data confirm this observation, with an overall 11·5 per cent rate of non-specific interventions (21 of 183).

Only 14 patients (7·7 per cent) had specifically liver-related interventions, which were related to high-grade injury in every case. Of interest, four of these 14 patients sustained additional high-grade splenic lesions that required an immediate splenectomy. Other accompanying intra-abdominal lesions were often found, including mesenteric avulsions or contusions of intestinal structures. From the operative notes of these patients with multiple injuries, it could be seen that bleeding from the liver laceration had been given priority, and these surgical interventions were therefore defined as 'liver related'.

Data are sparse concerning the clinical relevance of collateral intra-abdominal damage in patients with liver injury. The present results suggest that trauma surgeons should expect extrahepatic abdominal damage in every other patient with a liver injury (94 of the 183 patients in the present study). The mean(s.d.) AIS for these lesions was

2·5(0·8) (moderate injury) (range 1–4); hence the clinical impact was highly variable. Overall, 73 (78 per cent) of the 94 patients with collateral intra-abdominal injuries could be treated conservatively, but the other 21 (22 per cent) required immediate surgery. Thus, lack of attention to concomitant intra-abdominal damage in patients with liver injury may affect the outcome adversely.

The overall mortality rate of patients in the present study was 16·9 per cent, in keeping with rates reported previously[3,23,26]. Interestingly, patients with low-grade liver injury had a higher overall mortality rate than those with high-grade injury (21·6 *versus* 11 per cent; $P = 0·094$). This contrasts with other findings in the literature, as several authors have reported a relationship between mortality rate and grade of liver injury[2,9,13,27,28]. The present results are in agreement with this when considering liver-related deaths, but not for mortality from all causes. The grade of liver injury in the subgroup of 22 patients who died from collateral damage was low (either 1 or 2), and therefore the outcome was more dependent on the extrahepatic injuries. Thus, for patients with multiple injuries the classification of Moore and colleagues[19,20] may not predict mortality accurately. However, it may have predictive value for the development of intra- and extra-abdominal complications.

Of the nine deaths related to the liver injury, eight were early as a result of exsanguination, often due to involvement of central liver veins, and one was delayed until day 38 when fulminant abdominal sepsis caused multiorgan failure. Central hepatic vein involvement can be difficult to handle and may predict fatality. The present results are in accord with those of Asensio and co-workers[12], who observed a mortality rate of 87 per cent when direct attempts were made to repair hepatic veins or the retrohepatic caval vein.

The present authors believe that the liver lesion is not the limiting factor for the overall mortality of polytraumatized patients and that the initial trauma management algorithm can be designed independently from the grade of liver injury. In haemodynamically stable patients with blunt abdominal injury, contrast-enhanced CT is mandatory to detect an arterial contrast blush. This is probably the only test that is relevant therapeutically.

Conservative management of blunt liver injury represents a safe treatment option even in patients with high-grade injury (grades 3–5), with a moderate probability of liver-related complications (11 per cent). However, there is a considerable rate of extra-abdominal complications (17 per cent). The present data highlight the need to give high priority to the overall pattern of injury, including high-grade abdominal, thoracic and head injuries, in patients with blunt liver trauma. The impact of these concomitant injuries, especially extrahepatic lesions, on morbidity and mortality was significant in this series, and had a major effect on outcome. The proposed trauma management algorithm, which is independent of the grade of liver injury, would appear to offer safe management of patients with hepatic injury.

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