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Eleven Years of Liver Trauma: The Scottish Experience

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Abstract. The aim of this population based study was to assess the incidence, mechanisms, management, and outcome of patients who sustained hepatic trauma in Scotland (population 5 million) over the period 1992–2002. The Scottish Trauma Audit Group database was searched for details of any patient with liver trauma. Data on identified patients were analyzed for demographic information, mechanisms of injury, associated injuries, hemodynamic stability on presentation, management, and outcome. A total of 783 patients were identified as having sustained liver trauma. The male-to-female ratio was 3:1 with a median age of 31 years. Blunt trauma (especially road traffic accidents) accounted for 69% of injuries. Liver trauma was associated with injuries to the chest, head, and abdominal injuries other than liver injury; most commonly spleen and kidneys. In all, 166 patients died in the emergency department, and a further 164 died in hospital. The mortality rate was higher in patients with increasing age ($p < 0.001$), hemodynamic instability ($p < 0.001$), blunt trauma ($p < 0.001$), and increasing severity of liver injury ($p < 0.001$). The incidence of liver trauma in Scotland is low, but it accounts for significant mortality. Associated injuries were common. Outcome was worse in patients with advanced age, blunt trauma, multiple injuries and those requiring an immediate laparotomy.

In the United Kingdom trauma remains a leading cause of death and disability, particularly among young adults [1], and of those who sustain abdominal trauma, the liver is most frequently injured organ [2]. In Western Europe liver trauma remains a relatively rare occurrence, but it is associated with significant morbidity and mortality [3]. Respiratory problems, hemorrhage, sepsis, and bile leaks are common complications [4], and liver injuries are often associated with other life-threatening injuries.

Over the last two decades there have been fundamental changes in the surgical management of liver trauma. Firstly it has been recognized that the majority of liver injuries stop bleeding spontaneously [5–7]. In addition, computed tomography (CT) has become increasingly affordable and available. As a consequence of these changes, there has been a trend toward non-operative management of patients who have sustained significant hepatic trauma but remain hemodynamically stable [8]. It has also become apparent that this strategy can be successful in selected patients who are initially unstable but respond to the administration of intravenous fluids or blood [9].

A proportion of patients with hepatic trauma will require a laparotomy, either as a component of their initial resuscitation or as a result of the failure of non-operative management. Historically the results of laparotomy for major liver trauma have been poor, with many patients succumbing to the lethal combination of hypothermia, acidosis, and coagulopathy. Advances in surgery (perihepatic packing with planned reoperation, mesh wrapping, intrahepatic tamponade [10], and venovenous bypass [11]) and critical care maybe of benefit to some of this group of patients.

It seems likely that many of these advances will, for the foreseeable future, only be offered by selected surgeons (in conjunction with a specialist team of anaesthetists and radiologists) in specialist centers. The role of the non-specialist surgeon dealing with a severe liver injury may be limited to the placement of perihepatic packs prior to patient transfer [10]. Therefore there is a need for accurate epidemiological data about hepatic trauma to ensure the optimal provision of tertiary services and the development of working relationships and transfer protocols between recognized centers and peripheral hospitals. Liver trauma can often be surprisingly amenable to transfer for definitive surgery, and unlike splenic bleeding, deterioration is usually a gradual process. Continued hemorrhage tends to present as a decrease in hemoglobin concentration and an increase in transfusion requirements rather than a sudden event with associated hemodynamic instability [12].

This article reviews the epidemiology of liver trauma in Scotland (population 5 million) between the years 1992 and 2002. Accident and emergency services for major trauma are provided by seven teaching hospitals and nineteen district general hospitals. Four hospitals regularly undertake liver resectional surgery, and one of these is also the regional liver transplant unit.

The aim of this population-based study was to investigate the incidence, mechanisms of injury, management, and outcome of patients sustaining hepatic trauma in Scotland over an 11-year period in principally an adult population.

All work was done in Edinburgh, Scotland, United Kingdom.

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Table 1. Description of hepatic injuries using the Abbreviated Injury Scale.

Grade	Liver injury	
I	**Contusion**	Subcapsular, < 10% surface area
	Laceration	Capsular tear, <1 cm parenchymal depth
II	**Contusion**	Subcapsular, 10%–50% surface area
		Intraparenchymal, < 10 cm in diameter
	Laceration	1–3 m parenchymal depth, < 10 cm in length
III	**Contusion**	Subcapsular, >50% surface area or expanding
		Ruptured subcapsular or parenchymal hematoma
		Intraparenchymal hematoma > 10 cm or expanding
	Laceration	> 3 cm parenchymal depth, major duct involvement
IV	**Laceration**	Parenchymal disruption involving 25%–75% of hepatic lobe or one to three Couinaud segments within a single lobe or multiple lacerations > 3 cm deep
V	**Laceration**	Parenchymal disruption involving > 75% of hepatic lobe or more than three Couinaud segments within a single lobe.
	Vascular	Juxtahepatic venous injuries i.e., retrohepatic cava/central major hepatic veins
VI	**Vascular**	Hepatic avulsion (total separation of all vascular attachments)

Methods

The Scottish Trauma Audit Group (STAG) was established in 1992. It is a centrally funded organization intended to improve Accident and Emergency services in Scotland. The number of hospitals contributing to the audit increased each year to 11 by 1995, and included 25 major Scottish trauma units from 1999, until data collection finished in 2002. STAG recorded information on all trauma patients who were admitted to hospital for at least 3 days (or who died during the first 3 days of admission) or were managed in the resuscitation room. STAG did not include patients who died at the scene or on their way to hospital. Patients who arrived in the Accident and Emergency department in a state of cardio-respiratory arrest and whose period of attempted resuscitation did not exceed 15 minutes were also excluded from the database, as were patients over 65 years old with an isolated fractured neck of femur or pubic ramus. No pediatric data (age less than 13 years) are collected.

Patients meeting the above criteria were initially identified in the Accident and Emergency department and followed up by a local STAG co-ordinator who collected details on patient demographics, type and mechanism of injury, hemodynamic stability on presentation, injuries sustained, management, and outcome. Patients were followed to 3 months, discharge, or death. STAG recorded the type of first operation undertaken along with the timing of the operation and the grade of surgeon and anaesthetist involved, but not details of any subsequent operations. Injuries were described and scored using the Abbreviated Injury Scale (AIS) 1990 revision developed by the American Association for Automotive Medicine [13]. Liver trauma patients were defined as those sustaining any of the AIS codes 541810 to 541840 (Table 1). (When describing associated injuries in other body regions we discounted superficial skin injuries of AIS grade 1). All scoring was checked centrally to assure consistency. Injury Severity Score (ISS) was determined to assess the severity of overall injuries sustained [14]. The average patient capture rate from participating hospitals was 95% [15].

Table 2. Characteristic of patients sustaining blunt and penetrating liver trauma.

	Blunt liver trauma	Penetrating liver trauma	p Value
Number of patients	542	241	
Median age	32	28	$p < 0.001$[a]
Percentage male	69%	91%	$p < 0.001$[b]
Median Glasgow Coma Scale on admission	11.5	15	$p < 0.001$[a]
Median Injury Severity Score	34	13	$p < 0.001$[a]
Hemodynamic instability on admission[c]	36%	24%	$p < 0.001$[b]

[a]Mann-Whitney U-test.
[b]Fisher exact test.
[c]Defined as a systolic blood pressure < 90 mmHg.

Table 3. Mechanism of injury among liver trauma patients in Scotland.

Mechanism of injury	Number of patients
Road traffic accident	421 (54%)
Assault: penetrating[a]	226 (29%)
Assault: blunt	17 (2%)
Fall	79 (10%)
Sports injury	4 (1%)
Other[b]	36 (5%)
Total	783

[a]In 2002, the only year for which data were available, 29 (91%) of penetrating assaults were stab wounds, compared to only three (9%) gunshot wounds.
[b]Mostly crush and industrial injuries.

We tested differences between subgroups of these patients using Fisher exact probability tests for proportions, and the Mann-Whitney U-test. SPSS V11.0 was used throughout.

Results

During the period 1992–2002 a total of 52,676 patients were recorded on the STAG database, of whom 783 (1.5%) had sustained liver trauma. In 2000, when data were collected from all but two of the smaller trauma centers, 103 patients sustained liver injuries, giving a minimum incidence of 2.4 liver trauma patients per 100,000 per annum among Scotland's adult population. Of the 783 liver trauma patients, 330 (42%) died: 166 died in the Accident and Emergency Department and a further 164 died in hospital.

The median age of patients was 31 years (range: 13–91 years) and 76% were male. Liver trauma was commonest in young males: 43% of the patients in this series were men aged between 20 and 39 years old. Increasing age was associated with an increasing mortality rate ($p < 0.001$). Blunt liver trauma (69%) occurred more frequently than penetrating liver trauma (31%) and was associated with a significantly greater mortality rate ($p < 0.001$). Patients sustaining blunt trauma tended to be older, have more serious injuries, and were less male biased (Table 2). Road traffic accidents (RTAs) and penetrating assaults together comprised more than 80% of all injury mechanisms (Table 3).

Moderate (AIS = 2) liver injuries were most frequent, but almost a third of patients had more serious (AIS ≥ 3) liver injuries. Both mortality rates and overall injury severity increased with increasing severity of liver injury (both $p < 0.001$; Table 4).

Table 4. Details of Abbreviated Injury Scale (AIS) grade of liver trauma, percentage of patients who died, and median Injury Severity Score (ISS) for patients sustaining liver trauma.

AIS grade	N (%)	N died (% died)	Median ISS
2	541 (69%)	189 (35%)	22
3	114 (15%)	40 (35%)	22
4	104 (13%)	82 (79%)	48
5	22 (3%)	17 (77%)	43
6	2 (0%)	2 (100%)	75

A total of (702 (90%) liver trauma patients had other (associated) non-liver injuries that could be classified as moderate severity (AIS ≥ 2) or worse. Among these were 671 patients with head, chest, and/or other abdominal injuries (Fig. 1). Blunt trauma patients were more likely to have associated non-hepatic injuries than penetrating trauma patients (95% versus 79%, $p <$ 0.001).

It was difficult to determine the exact cause of death in patients (especially those who had sustained blunt trauma). Post mortem reports often used the phrase "multiple injuries" as the cause of death in these situations. Therefore it was impossible to identify which specific injury, or group of injuries was directly responsible for the death of many patients in this study. Head injuries were assumed to be a significant factor in the death of many of these patients, as 166 of the patients in this study had a serious head injury (defined as AIS 4 or above) and 139 of these patients died.

Altogether, 483 (62%) of liver trauma patients also had other abdominal injuries (AIS ≥ 2). These injuries were detected at post-mortem (235 patients), at laparotomy (207 patients) or by radiological imaging (41 patients). The organs most commonly involved were spleen 188 (24% of all patients with liver trauma), kidney 167 (21%), mesentery 135 (17%), colon 71 (9%), stomach 56 (7%), pancreas 52 (7%), duodenum 32 (4%), bladder 28 (4%), gallbladder 22 (3%), inferior vena cava 15 (2%), and aorta 13 (2%). The presence of other abdominal injuries was associated with a lower survival ($p < 0.001$).

Eighty-six patients (11%) had an ISS between 1 and 8, and 141 patients (18%) had an ISS between 9 and 15. The remaining 556 patients (71%) had an ISS greater than 15, a commonly accepted lower threshold defining major trauma. Indeed, 431 liver trauma patients (55%) had an ISS of 25 or more, compared to only 7% of patients in the entire STAG trauma database. Predictably, mortality was greater in those with a higher ISS ($p < 0.001$). Some 254 patients (32%) with liver trauma were hemodynamically unstable (systolic blood pressure less than 90 mmHg) on arrival in the Accident and Emergency Department. These patients were more likely to die than those who were stable on arrival (77% versus 42%, $p < 0.001$).

Of the 166 patients who died in the Accident and Emergency Department, 11 patients underwent an unsuccessful emergency laparotomy or thoraco-laparotomy in the resuscitation room. Among the remaining 617 patients who were admitted for further treatment, 382 patients (62%) had a laparotomy as their first operation, and 118 patients (19%) had a different first operation. Of those who had operations other than laparotomies as first operations, at least 33 went on to have later laparotomies, as indicated by the diagnostic source recorded with their liver injuries. This gives an overall laparotomy rate of 68% among admitted patients. This may be a slight underestimate because STAG only records one diagnostic source with each injury: it is possible that some of the remaining 85 patients who had operations other than laparotomies went on to have later laparotomies. Another 113 patients (19%) had no operation during their in-patient stay, and 29 of them died (24 within 2 days of admission).

For the 382 patients who underwent a laparotomy as a primary surgical procedure 194 patients (51%) underwent surgery within 2 hours of arrival in hospital, 90 patients (24%) had a laparotomy between 2 and 4 hours of arrival, and 84 patients (22%) were operated on between 4 and 24 hours after arrival. Only 12 patients (3%) had a laparotomy more than 24 hours after arriving in the Accident and Emergency department. The exact time of the laparotomy was not available for 2 of the 382 patients. Mortality was highest in those patients transferred rapidly (within 1 hour) to theatre (47% versus 21%, $p <0.001$). Seventy percent of laparotomies had a consultant surgeon present, and in 57% a consultant anaesthetist was involved in the management. Mortality was greatest in those who had a consultant (rather than a trainee) surgeon (30% versus 13%, $p < 0.001$) and anaesthetist (34% versus 12%, $p < 0.001$) present during their operation.

The relative influence of liver injury AIS on survival compared to other types of injury scores (head, chest, other abdomen, and extremity), age, sex, type of injury (blunt or penetrating), systolic blood pressure at presentation, and time to operation was assessed in a logistic regression analysis (Table 5). When the influence of all these different factors associated with increased mortality were investigated in combination, mortality continued to increase with injury severity in the liver and all other body regions except extremity injuries (Table 5). Mortality was still associated with increasing age and was higher among patients who were hemodynamically unstable on presentation and those who were transferred to the operating room within 1 hour.

Among the 617 patients who did not die in the Accident and Emergency department, 296 (48%) patients were admitted to the Intensive Therapy Unit (ITU). The median length of stay in ITU was 4 days (inter-quartile range: 1 to 12 days), with some 21% of ITU patients requiring 2 or more weeks of ITU care.

Discussion

In a recent Swedish population-based study of liver trauma, it was calculated that the incidence of hepatic injury in Stockholm county was 2.95 per 100 000 per annum [16]. Although this is slightly higher than the Scottish incidence of 2.4 per 100,000 per annum, three quarters of the data in the Swedish study was derived from post mortem examinations of patients who had died before receiving any medical attention. Such data are not included in the STAG database. Hence it would appear that the incidence of liver trauma in Scotland may be up to three times greater than in the Swedish population.

Seventy-six percent of liver trauma patients in our study were male. A male predominance has been demonstrated in almost every other liver trauma series, including studies from the UK [17] (79%), other parts of Western Europe (67%–74% [16, 18, 19] South Africa [20] (81%), Egypt [21] (65%) and the USA [22–24] (61%–79%).

We found a higher frequency of liver trauma among younger patients. In 1991, Wilson [4] reviewed many series of liver trauma and observed that the patients' average age tended to lie between 25 and 30. More recent work confirms that this global pattern continues. In the last decade large liver trauma series from

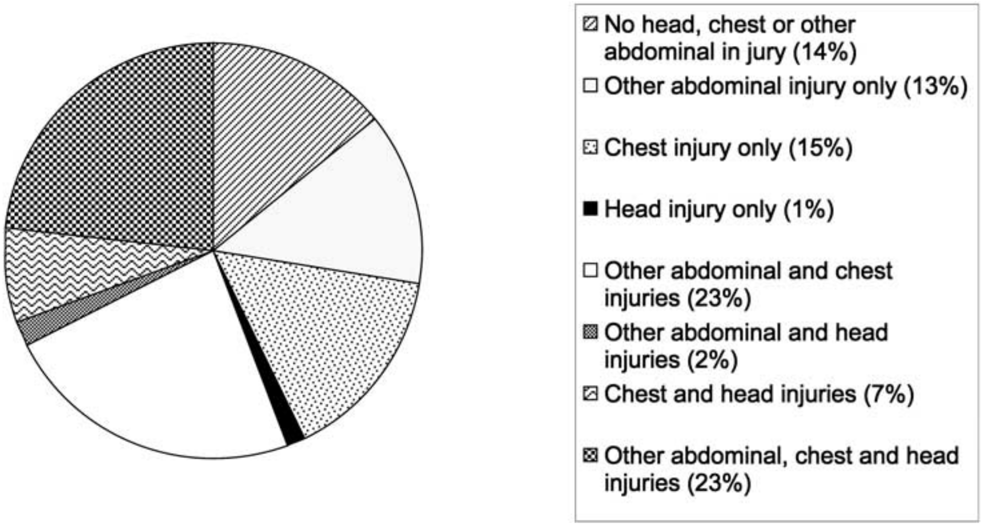

Fig. 1. Non-liver injuries in patients sustaining liver trauma in Scotland

Table 5. Multivariate analysis of factors affecting survival of patients with liver injuries.

Explanatory variables	Category	Odds ratio (Exp *B*)	95% CI for Exp *B*	*P*	% of variation explained
Chest AIS		0.63	0.54–0.73	< 0.001	37.4%
Head AIS		0.53	0.47–0.61	< 0.001	52.1%
Systolic blood pressure		4.30	2.59–7.15	< 0.001	61.3%
Time to theatre	< 1 hour			< 0.001	67.7%
	1–2 hours	4.78	2.07–11.08		
	2–4 hours	5.91	2.32–15.09		
	4–24 hours	8.16	2.92–22.81		
	> 24 hours	31.74	5.80–174		
	No operation	0.68	0.30–1.51		
Other abdominal AIS		0.65	0.55–0.76	< 0.001	71.0%
Age		0.97	0.96–0.99	< 0.001	72.0%
Liver AIS		0.59	0.46–0.79	< 0.001	73.1%
constant		53.63			

Variables are listed in the order in which they entered a logistic regression model using a forward stepwise selection process. Systolic blood pressure was entered as 0 = hemodynamically unstable, 1 = stable (> 90 mmHg). For all variables except time to operation Exp B is the change in odds of survival associated with a one unit increase in that variable (e.g., from AIS score 3 to AIS score 4). For time to operation Exp B is the factor by which the odds of survival increase when the category is compared with patients who went to the operating room within 1 hour. All values of Exp B below one indicate that survival decreases as the variable increases, whereas values above one indicate that survival increases as that variable increases. Other variables tested during the model-building process (but excluded from the final model at $p > 0.05$) were sex, type of injury (blunt/penetrating), and extremity injury AIS.

Germany [19], South Africa [20], and the USA [24] have shown mean ages of 35, 32, and 30, respectively.

Another trend that was very apparent in this study is the prevalence (69%) of patients who sustained blunt trauma. Other European authors have reported even higher frequencies of blunt trauma. German and Swiss authors found that blunt abdominal trauma was responsible for 80%–90 % of liver trauma [25, 26]. In Cambridge, UK, blunt trauma was responsible for 94% of injuries in patients presenting to a specialist unit [27] and in the recent Stockholm study [16] blunt trauma was the cause of 91% of liver injuries. This contrasts sharply with the experience in some other centers. Krige [20], reporting a South African experience, found that 66% of 446 patients had sustained penetrating liver trauma. The bulk of the published work on liver trauma comes from the North American trauma centres, where penetrating trauma is much more common than in Europe. Feliciano et al. [28] reviewed 1000 patients with liver trauma and found that penetrating trauma was responsible for 86% of hepatic injuries. Fabian found a 65% incidence of penetrating trauma in 482 patients [22]. In these three studies abdominal gunshot wounds were responsible for 31-63% of the penetrating injuries. This is a further important difference between European and North American/South African reports. European series such as ours have a significantly higher incidence of stab injuries and a much lower incidence of gunshot wounds.

In our study, over half (54%) of patients with liver trauma had been involved in road traffic accidents. This supports the findings of other UK studies: for example, Brammer [3] and John [17] observed that 67% and 70% of liver injuries managed in their respective specialist units (Birmingham and Edinburgh) were caused by road traffic accidents.

Initial hemodynamic instability (systolic blood pressure less than 90 mmHg when patients arrived at the Accident and Emergency Department) was recorded in 32% of our liver study group. These patients had a higher mortality rate than those who had a blood pressure greater than 90 mmHg ($p < 0.001$). Similarly, those patients who required an early laparotomy had a higher mortality rate ($p < 0.001$). This could be explained by blood loss, as many early deaths can be attributed to uncontrollable hemorrhage [10]. Shock on admission has previously been thought to double mortality rates [4]. An increased emphasis on immediate damage-control surgery and planned reoperation combined with the recognition of the catastrophic final pathway of hypothermia, coagulation, and acidosis [29] may reduce the mortality rate in these critically ill patients.

Most of the patients in this series (69%) sustained AIS grade 2 hepatic injury. This finding was similar to results of the earlier Scottish study [17], which showed a 70% incidence (albeit using an older scoring system) of simple injuries. This differed from a Birmingham series in which Brammer [3] found a much higher proportion of patients with AIS grade 3, 4, or 5 injuries. However, their data were gathered from a cohort of patients who had been transferred to a tertiary referral center for surgery or aggressive non-operative management. In our series, 16% of the patients had a grade 4 or 5 injury. This is remarkably similar to the work of Richardson [30], who reviewed 1842 patients who presented with liver trauma over a 25-year period. Likewise Pachter [31] found an incidence of 14% grade 4 and 5 injuries in their review of 411 liver injuries. Most surgeons would agree that it is the hemodynamic status (in combination with clinical and other parameters) that determines the need for laparotomy rather than the AIS grade per se. However, a multicenter review has shown that most cases of failed non-operative management occur in patients with grade 4 or 5 injuries [24]. Our study shows a high incidence of low-grade liver injury, combined with a predominance of blunt trauma in a patient population often hemodynamically stable on presentation. This suggests that the practice of non-operative management of liver trauma will be successful in the United Kingdom. Certainly, initial reports are encouraging [32].

Ninety percent of our 783 liver trauma patients sustained associated chest, head, orthopedic, or other abdominal injuries. This was expected as the common mechanisms of injury include road traffic accidents, assaults, and falls. Previous work by Wilson [4] suggests that associated injuries are seen in 63%–90% of patients with liver trauma and that more associated injuries are found with penetrating trauma than with blunt trauma. The opposite was true in our series: blunt trauma patients were more likely to have associated injuries than those with penetrating injuries. In our series, other abdominal (62%) and chest (56%) injuries predominate, which is to be expected given the location of the liver. Brammer [3] also noted that chest (40%) and other abdominal (19%) injuries were common. The high rate of associated injuries is an important finding, and it highlights the challenge of managing patients with multiple injuries. The presence of extrahepatic injuries can make it difficult to decide which patients can be managed conservatively. First, chest and major orthopedic injuries can contribute to hemodynamic compromise, and priorities for immediate management must be determined. Second, spinal cord and head injuries can alter hemodynamic and peritoneal signs. The finding that 62% of patients in our series had another intra-abdominal injury must also be highlighted. It is essential that the commonly injured organs are fully evaluated by CT scan if patients are to be managed conservatively. The 24% of patients with an associated splenic injury is a group that is at particularly high risk of sudden circulatory collapse. One of the recurring concerns in taking a non-operative approach is the possibility of a missed hollow viscus injury. Enteric injuries are notoriously difficult to spot on an abdominal trauma CT [33], although several studies suggest that only 0.5%–0.9 [24–34] of liver trauma patients who are managed conservatively will have a missed hollow viscus injury.

Of the patients in our series, 166 (21%) died in the resuscitation room and a further 164 (21%) died in hospital. The high overall mortality rate of 42% in this study can be related to the high incidence of blunt injuries which have consistently been shown to be associated with a higher mortality rate than penetrating injuries. In addition, the population audited by STAG consists of all seriously injured patients managed in Scottish Accident and Emergency departments. Some of the patients in this study will have died in the Accident and Emergency department as a result of catastrophic head injury, spinal cord transection, thoracic injuries, or massive hemorrhage and then had liver injuries discovered at post mortem. This means that our mortality rate will be greater than in studies where all patients have undergone, or been considered for surgery.

Liver injuries are relatively rare in Scottish trauma patients, but they account for considerable mortality. Most victims will have sustained other significant injuries and may require a multi-disciplinary approach to treatment. Recognized liver injuries should be discussed, at an early stage, with specialist liver surgeons to ensure that appropriate operative or non-operative management is undertaken.

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