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A Quarter Century Experience in Liver Trauma: A Plea for Early Computed Tomography and Conservative Management for all Hemodynamically Stable Patients

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Abstract
Background Advances in diagnostic imaging and the introduction of damage control strategy in trauma have influenced our approach to treating liver trauma patients. The objective of the present study was to investigate the impact of change in liver trauma management on outcome.
Methods A total of 468 consecutive patients with liver trauma treated between 1986 and 2010 at a single level 1 trauma center were reviewed. Mechanisms of injury, diagnostic imaging, hepatic and associated injuries, management (operative [OM] vs. nonoperative [NOM]), and outcome were evaluated. The main outcome analysis compared mortality for the early study period (1986–1996) versus the later study period (1997–2010).
Results 395 patients (84%) presented with blunt liver trauma and 73 (16%) with penetrating liver trauma. Of these, 233 patients were treated with OM (50%) versus 235 with NOM (50%). The mortality rate was 33% for the early period and 20% for the later period (odds ratio 0.19; 95% CI 0.07–0.50, $P = 0.001$). A significantly increased use of computed tomography (CT) as the initial diagnostic modality was observed in the late period, which almost completely replaced peritoneal lavage and ultrasound. There was a significant shift to NOM in the later period (early 15%, late 63%) with a low conversion rate to OM of 4.2%. Age, degree of hepatic and head injury, injury severity, intubation at admission, and early period were independent predictors of mortality in the multivariate analysis.
Conclusions Integration of CT in early trauma-room management and shift to NOM in hemodynamically stable patients resulted in improved survival and should be the gold standard management for liver trauma.

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Introduction

Advances in imaging modalities, interventional radiology, critical care, and the introduction of damage control surgery during the past two decades have greatly influenced the diagnosis and treatment algorithm in trauma surgery. Especially, the development of new imaging techniques such as ultrasound and computed tomography (CT) has had a significant impact on the initial evaluation of patients with liver trauma, since the liver is the most commonly injured abdominal organ [1]. The further technical development of spiral CT in the 1990s resulted in "sub" second multi-slice scanners with dramatically shorter data acquisition times and

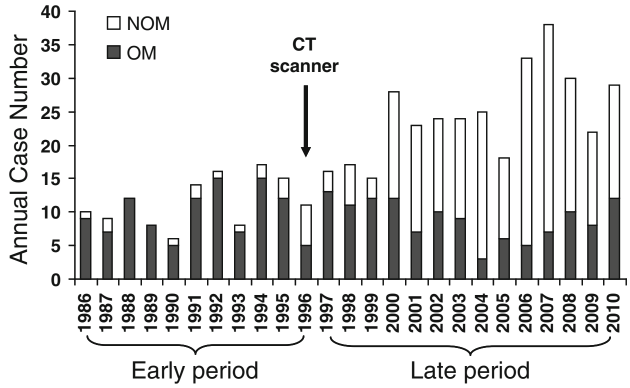

Fig. 1 Annual number of patients treated for liver trauma for the period 1986–2010. *Solid* and *open bars* represent case numbers of operative (OM) and nonoperative management (NOM). Damage control surgery was introduced in our center in the early 1990s and a computed tomography (CT) scanner was installed in our trauma room in 1996

better resolution than earlier CT scanners [2]. As a result, CT has been integrated as primary diagnostic tool in many trauma centers during the early resuscitation phase.

Another important change in trauma practice was the introduction of damage control surgery in the late 1980s and early 1990s [3]. Damage control is an operative strategy aimed to achieve physiological stability rather than complete immediate repair of injuries [4]. The concept of abbreviated laparotomy and planned re-laparotomy had been discussed for liver trauma in the beginning of the last century [5, 6]. The idea behind this concept is to prevent metabolic failure and uncontrolled bleeding, which are major contributors to early death in trauma surgery [7]. The benefit of damage control in liver trauma with liver packing and staged reoperation has become a standard treatment principle in patients requiring emergency laparotomy for severe liver trauma during the past two decades [8–10].

The worldwide trend toward integration of CT in early trauma-room management and the introduction of damage control surgery were adopted early in our trauma center (Fig. 1). An internal audit resulted in installation of a CT scanner in our trauma room in 1996. We present the 25-year experience of liver trauma management in a single level I urban trauma center before and after 1996, when a dramatic change in the treatment algorithm occurred. The objective of the present study was to investigate the impact of change in liver trauma management on outcome.

Patients and methods

Study design

Between January 1986 and December 2010, 468 patients were treated for liver trauma at the University Hospital Zurich, which includes a level I trauma center. All patients were identified from a prospective database, and all charts were retrospectively reviewed for demographics, clinical variables at admission (GCS, systolic blood pressure, heart rate, shock index, serum AST and ALT), injury trauma scores, mechanism of liver injury, diagnosis and treatment modality, and outcome variables. Systolic blood pressure and heart rate are the first recorded values at admission. The installation of a CT scanner in our trauma room in 1996 and the introduction of the damage control strategy in the early 1990s had a significant impact on the management of patients with liver trauma (Fig. 1). We performed the analysis comparing the early period (1986–1996) and the late period (1997–2010). We hypothesized that those changes resulted in a significant survival benefit in the late period. The study was approved by the Internal Review Board of the University Hospital Zurich (EK: 2011-0083/0).

Injury classification

The grade of liver injury was classified according to the revised 6-grade organ injury scale of the American Association for the Surgery of Trauma [11, 12]. Briefly, low-grade injuries were defined as grade I and II, and high-grade injuries were grades III to VI. The final classification of liver injury was based on the findings during laparotomy and/or on CT scans. In addition to the injury description by the American Association for the Surgery of Trauma, the CT diagnosis of portal tracking was graded as grade I injury. Associated injuries including liver trauma were graded according to the Abbreviated Injury Scale (AIS) for the 6 body regions head, face, chest, abdomen, extremities, and external. Based on the AIS injuries, the injury severity score (ISS) was calculated using the AIS grading system [13].

Initial diagnosis and treatment management

The initial modality, which primarily diagnosed liver trauma first was determined for each patient (Fig. 2), and the following four categories were defined: (1) positive diagnostic peritoneal lavage (DPL) followed by emergency surgery, (2) abdominal ultrasound, (3) computed tomography, and (4) surgery including emergency laparotomy and diagnostic laparoscopy. Liver traumas, which were initially treated by a conservative approach were classified as nonoperative management (NOM), whereas liver traumas requiring initial abdominal surgery including laparotomy or laparoscopy were defined as operative management (OM). Initial NOM of liver trauma, which had to be converted to OM, was considered as failure of NOM.

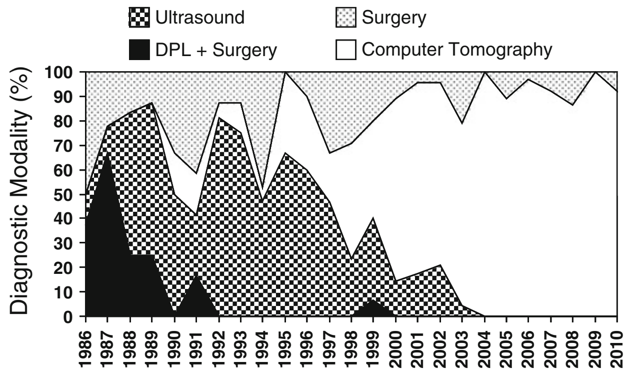

Fig. 2 Annual percentage distribution of initial diagnostic modality of liver trauma at admission for the period 1986–2010. The four diagnostic modalities are diagnostic peritoneal lavage (DPL) followed by laparotomy, abdominal ultrasound, computed tomography, and surgery including emergency laparotomy, and diagnostic laparoscopy

Primary and secondary endpoints

Each patient was followed for the entire period of hospitalization regardless of the outcome. In-hospital mortality was the primary endpoint of the study. Secondary endpoints included 24 h mortality, length of intensive care unit (ICU) and hospital stay, initial transfusion requirement, NOM, failure of NOM, and total operative time of OM. The total operative time of initial OM included time of surgery for liver injury and associated injuries.

Statistics

We had less than 2% missing data for the main analyses, and we therefore decided not to perform a multiple imputation and base the analyses on complete cases. For the description of the OM and NOM and all variables describing patient care during hospital admission, we used medians and interquartile ranges (IQR, 25th to 75th percentile) for continuous variables and absolute numbers and proportions for binary data. The main analysis compared in-hospital and 24 h mortality between the early and late period groups. Because this was not a randomized trial of patients admitted to the Emergency Room, we adjusted the analysis for confounders in order to make the early and late period groups as comparable as possible. In a multivariable logistic regression model we compared in-hospital mortality between the early and late period study groups while adjusting age, sex, intubation at admission, severity of liver injury, severity of head injury (AIS head), and severity of global injury (ISS), all assessed at admission. We also adjusted for the length of hospital stay to take the time at risk for dying into consideration. For all results, we reported point estimates, 95% confidence intervals (CI), and P values ($\leq$0.05 considered significant). We performed the statistical analyses with the statistical program STATA (version 11, Stata Corp., College Station, TX).

Results

Initial presentation at admission

During the 25-year study period, 468 patients (female $n = 171$, 37%; male $n = 297$, 63%) were admitted for liver trauma with ($n = 437$, 93%) or without ($n = 31$, 7%) associated extrahepatic injuries. The majority of patients had blunt liver traumas ($n = 365$, 84%), while 16% of patients ($n = 73$) were admitted for penetrating liver traumas. At admission, 185 patients (39%) were intubated, and the majority of patients ($n = 349$, 75%) presented with polytrauma.

There were demographic differences between the early and late groups. For example, the population of the early period group was younger (28 vs. 34.5 years, $P = 0.081$) and was composed of more male patients (73% vs. 60%) (Table 1). Although median heart rate and shock index were significantly lower for the late period patients, there was no significant difference in median Glasgow Coma Score (GCS) and rate of intubation at admission between the two periods. In terms of liver injury, the population of the late period had a lower rate of penetrating and high-grade liver traumas, as well as a slightly lower median hepatic injury degree. On the other hand, the median AIS of head and median ISS were comparable for the two groups (Table 1).

Initial diagnosis of liver trauma

At the beginning of the study period, the majority of liver traumas was diagnosed by DPL followed by laparotomy (Fig. 2). This diagnostic approach disappeared in the following years and was replaced by abdominal ultrasound. After the installation of the CT scanner in our trauma room in 1996, there was a dramatic shift to CT as the initial diagnostic modality of liver trauma. Although only 11% of liver traumas were initially diagnosed by CT in the early period, the majority of liver traumas (72%) were diagnosed by CT in the late period. Further observation of trends during recent years shows that CT replaced the abdominal ultrasound as the initial diagnostic tool in almost all hemodynamically stable patients.

Severity of hepatic injury in relation to other injury and outcome variables

There was no correlation between the severity grade of hepatic injury and other injury scores (AIS-head, ISS)

Table 1 Patient characteristics at admission

Variable	Early period (1986–1996) $n = 126$	Late period (1997–2010) $n = 342$	*P* value
Age, median (IQR)	28.0 (22.7–42.3)	34.5 (22.7–48.1)	0.081
Sex, males, *n* (%)	92 (73.0)	205 (59.9)	0.009
Systolic BP, median (IQR)	120 (100–140)	120 (105–140)	0.641
Heart rate, median (IQR)	100 (88–120)	90 (78–105)	<0.001
Shock index, median (IQR)[a]	0.80 (0.69–1.09)	0.74 (0.61–0.91)	<0.001
GCS, median (IQR)	10 (3–15)	14 (3–15)	0.391
Intubated, *n* (%)	56 (44.4)	129 (38.1)	0.211
Polytrauma, *n* (%)	84 (68.9)	256 (74.9)	0.198
Liver injury, median (IQR)	2.5 (2–3)	2 (1–3)	<0.001
High grade liver injury, *n* (%)	63 (50.0)	119 (34.5)	0.002
Penetrating/blunt, *n*/*n* (%/%)	28/98 (22.2/77.8)	45/297 (13.2/86.8)	0.048
AIS head, median (IQR)	0 (0–3)	1 (0–3)	0.407
AIS head ≥3, *n* (%)	36 (28.6)	100 (29.2)	0.888
ISS, median (IQR)	34 (25–45)	45.5 (25–48)	0.401

BP blood pressure, *ISS* Injury Severity Score, *GCS* Glasgow Coma Scale, *AIS* Abbreviated Injury Score, *IQR* interquartile range from 25th to 75th percentile

[a] Calculated as heart rate divided by systolic BP (normal range: 0.5–0.7)

Table 2 Hepatic injury grade in relation to other injury and outcome variables

Hepatic injury Grade	Intubated *n* (%)	AIS-head Median (IQR)	ISS Median (IQR)	LOS (days)[a] Median (IQR)	In-hospital mortality *n* (%)
I (*n* = 139)	56 (40.6)	1 (0–4)	34 (22–41)	18 (8–32)	25 (18.0)
II (*n* = 147)	54 (37.0)	0 (0–3)	41 (25–50)	18 (11–29)	27 (18.4)
III (*n* = 111)	42 (37.8)	0 (0–3)	38 (27–50)	16 (11–27)	29 (26.1)
IV (*n* = 49)	19 (39.6)	0 (0–2)	41 (34–50)	25 (4–34)	15 (30.6)
V (*n* = 21)	14 (66.7)	0 (0–3)	41 (25–50)	41 (26–54)	13 (61.9)
VI (*n* = 1)	1 (100)	(1 observation)	(1 observation)	(1 observation)	1 (100)

[a] Length of hospital stay without deaths

(Table 2). Although 67% ($n = 14$) of patients with grade V liver injury were intubated at admission, the intubation rate among patients with grade I–IV injuries was comparable (37–41%). Table 2 also shows that increasing severity of hepatic injury translated into a longer length of hospitalization (LOS) and higher in-hospital mortality rate.

Nonoperative versus operative management

Among the 468 patients with liver trauma, 235 (50%) were treated with NOM and 233 (50%) with OM. After 1996, there was a significant shift toward NOM (Fig. 1). While only 15% of patients were treated conservatively in the early period, 63% of the patients underwent NOM in the late period. The observed shift occurred in all groups of each hepatic injury grade (Table 3). Although the percentage of OM decreased from 85% in the early period to 37% in the late period, the case volume of OM was comparable for both periods (early $n = 107$, late $n = 126$).

Table 3 Operative and nonoperative management during early (1986–1996) and late period (1997–2010) in relation to the hepatic injury grade

Hepatic injury grade	Operative (*n* = 233)		Nonoperative (*n* = 235)	
	Early (*n* = 107)	Late (*n* = 126)	Early (*n* = 19)	Late (*n* = 216)
I (*n* = 139)	15 (71%)	24 (20%)	6 (29%)	94 (80%)
II (*n* = 147)	36 (86%)	35 (33%)	6 (14%)	70 (67%)
III (*n* = 111)	35 (88%)	34 (48%)	5 (12%)	37 (52%)
IV (*n* = 49)	14 (93%)	23 (68%)	1 (7%)	11 (32%)
V (*n* = 21)	6 (86%)	10 (71%)	1 (14%)	4 (29%)
VI (*n* = 1)	1	0	0	0

Percentages in *parentheses* refer to the total number of the corresponding period

Nonoperative management of liver trauma

The majority of patients (75%), who were managed expectantly had low-grade injuries (grade I and II). Eleven patients of the initially selected 235 patients for NOM required a later operation for various reasons, resulting in a

Table 4 Conversion to operative management after failure of nonoperative management

Patient no.	Year	Hepatic injury grade	Reason for conversion	Operative findings responsible for conversion	In-hospital mortality
1	1986	II	Hypotension, ultrasound revealed free fluid	Liver laceration	No
2	1987	III	Hypotension, initial negative DPL negative, repeated DLP positive	Multiple liver laceration in both lobes	Yes
3	1989	II	Tachycardia, ultrasound revealed free fluid	Liver laceration	No
4	1992	I	Hemoglobin drop and hypotension	Delayed splenic rupture, capsular tear liver	Yes
5	2000	IV	Septic signs, CT revealed liver abscess	Infected liver necrosis	No
6	2002	V	Hypotension requiring volume transfusion	Disruption right hemi liver	No
7	2004	I	Abdominal tenderness and peritonitis	Small bowel perforation	No
8	2005	I	Abdominal pain and peritonitis	Sigmoid perforation	No
9	2007	II	Persistent bleeding	Negative laparotomy	No
10	2007	I	Abdominal compartment syndrome	No liver laceration	No
11	2007	I	Abdominal compartment syndrome	No liver laceration	No

conversion rate of 4.2% (Table 4). Five of the eleven converted patients had liver-specific findings during surgery, and the remaining 6 patients had either extrahepatic or negative findings during laparotomy. The liver-specific failure rate of NOM was even lower at 2.2%, demonstrating the high success rate of NOM. Nine of the eleven converted patients (82%) survived.

Operative management of liver trauma

Among the 233 patients with OM, 123 patients (53%) underwent abdominal surgery for high-grade (III–VI) liver injuries. The rate of high-grade liver injuries (52% vs. 53%) and the mean ISS (37 vs. 40) were comparable for the early and late periods. The mean total operative time was significantly shorter for the late period compared to the early period (124 vs. 229 min, $P < 0.001$). The median number of transfused packed red blood cells (PRBC) units (11 vs. 9) and the rate of mass transfusion with $\geq$15 units of PRBC (40% vs. 36%) were similar between both time periods. Although there was an equal distribution of high-grade injuries between the early ($n = 56$, 52%) and late ($n = 67$, 53%) periods, significantly more packing procedures and fewer suturing procedures were performed in the late period compared to the early period (Table 5). The in-hospital mortality of OM was not significantly different between the early (39/107, 36%) and late periods (41/126, 32%) but significantly fewer patients who survived the first 24 h after admission died during the hospitalization in the late period (7/126 vs. 14/107, $P = 0.012$).

Outcome analysis

The change in the management after 1996 had a great impact on in-hospital mortality (Table 6). Sixty-nine patients (20%) died in the hospital in the late period as compared to 41 (33%) in the early period, resulting in an adjusted odds ratio of 0.19 (95% CI 0.07–0.50, $P = 0.001$). Thus, based on the upper limit of the confidence interval, there is at least a 50% reduction of in-hospital mortality for the late period compared to the early period. The 24 h mortality was also lower in the late period group (15.5% vs. 19.8%), but the risk of mortality was not significantly different (adjusted odds ratio 0.78, 95% CI 0.40–1.53, $P = 0.476$). Table 6 also shows that age, hepatic injury grade, AIS head trauma, ISS, and intubation status at admission were strong independent predictors of 24 h and in-hospital mortality. There was a significantly shorter length of ICU stay in the late period (5 vs. 10 days, $P = 0.002$), but the median hospital length of stay (LOS) was comparable for both periods (14 vs. 14 days, $P = 0.780$).

Table 5 Leading operative procedure in patients with operative management

Procedure[a]	Early period (1986–1996) $n = 107$	Late period (1997–2010) $n = 126$
Nil	3 (2.8%)	6 (4.8%)
Drainage	14 (13.1%)	15 (11.9%)
Local hemostasis[b]	11 (10.3%)	18 (14.3%)
Suturing	53 (49.5%)	25 (19.8%)
Resection	6 (5.6%)	6 (4.8%)
Packing	20 (18.7%)	53 (42.1%)

[a] For each operative case the leading procedure was listed according to following order nil < drainage < local hemostasis < suturing < resection < packing

[b] Includes electro and infrared coagulation, biomaterials (collagen sponge, oxidized regenerated cellulose gauze), and fibrin glue

Table 6 Comparison of the early study period (1986–1996) and the late study period (1997–2010) for 24 h and in-hospital mortality with adjustment for predictors of outcome

	Univariate associations Odds ratio (95% CI), *P* value	Multivariate associations Odds ratio (95% CI), *P* value
24 h mortality		
Period, 1997–2010 versus 1986–1996	0.74 (0.44–1.25), 0.264	0.78 (0.40–1.53), 0.476
Age, per year increase	1.02 (1.01–1.04), 0.004	1.03 (1.01–1.05), 0.001
Gender, male versus female	1.11 (0.66–1.84), 0.669	1.08 (0.57–2.03), 0.820
Hepatic injury, per point increase	1.51 (1.23–1.86), <0.001	1.53 (1.17–2.00), 0.002
AIS head trauma, per point increase	1.62 (1.42–1.84), <0.001	1.29 (1.08–1.54), 0.005
ISS, per point increase	1.09 (1.07–1.12), <0.001	1.06 (1.03–1.09), <0.001
Intubated at admission, yes versus no	8.32 (4.61–15.00), <0.001	3.81 (1.92–7.56), <0.001
In-hospital mortality[a]		
Period, 1997–2010 versus 1986–1996	0.52 (0.33–0.83), 0.006	0.19 (0.07–0.50), 0.001
Age, per year increase	1.02 (1.01–1.03), 0.002	1.06 (1.04–1.09), <0.001
Gender, male versus female	1.39 (0.88–2.19), 0.162	1.97 (0.82–4.78), 0.132
Hepatic injury, per point increase	1.48 (1.23–1.79), <0.001	1.98 (1.35–2.92), 0.001
AIS head trauma, per point increase	1.81 (1.59–2.05), <0.001	1.64 (1.26–2.14), <0.001
ISS, per point increase	1.10 (1.08–1.22), <0.001	1.07 (1.03–1.11), <0.001
Intubated at admission, yes versus no	11.43 (6.73–19.43), <0.001	8.26 (3.51–19.44), <0.001

[a] Adjusted for length of hospital stay

Discussion

This large cohort study mirrors the dramatic impact of advances in diagnostic imaging and the introduction of the damage control surgery on our approach to manage liver trauma during the past 25 years. The integration of the CT scanner in the trauma room resulted in a significant shift from OM to NOM after 1996 (Fig. 1). Furthermore, NOM proved to be highly successful, and the introduction of damage control surgery was reflected by the significantly shorter operative times and the higher perihepatic packing rate in the late period as compared to the early study period. These changes were associated with improved survival.

The major advantage of the present study is the long longitudinal observation over a quarter century with a defined change in infrastructure of the trauma room in a single center. Nevertheless, there are limitations of the study related to its retrospective nature. Although all patients were identified from a prospective database, the majority of data had to be retrospectively collected. However, important demographic, treatment, and outcome variables were completely identified for each patient, and less than 2% of data were missing for other variables. The high degree of completeness of data also allowed us to control for important confounders that needed to be considered in the analysis of this nonrandomized study.

One of the important findings of the study is the change in how we initially diagnosed liver trauma at admission over the past 25 years. In the very early period, DPL and laparotomy were the primary diagnostic tools (Fig. 2). In fact, DPL was the backbone of diagnosis of abdominal trauma from its introduction in 1964 [14]. This technique disappeared as primary diagnostic tool and was first replaced by ultrasound and later by CT. Although DPL is reported to be a highly accurate test with a low complication rate [15], the limitation of this technique is the potential detection failure of liver trauma in the absence of hematoperitoneum. During the late 1980s and early 1990s, abdominal ultrasound became the predominating initial diagnostic tool with the introduction of the concept of focused assessment with sonography for trauma (FAST). Although many studies report a high sensitivity of FAST for free fluid, the drawback in cases of liver trauma is related to the inappropriate diagnosis of the intra-abdominal bleeding site and grading of organ injury. With the installation of a CT scanner in our trauma room in 1996, CT became the leading diagnostic tool and remains so today (Figs. 1, 2). This change in infrastructure allows performance of multi-slice whole-body CT scans with very short acquisition times in hemodynamically stable and more recently even in hemodynamically unstable patients during the early resuscitation phase [16, 17]. The advantage of this technique is the improved grading of organ injury and the localization of the bleeding site.

Another striking change is the shift to nonoperative management of liver trauma after 1996 (Fig. 1). This change in management can most likely be attributed to the integration of CT in early trauma-room management. A significant proportion of conservatively managed liver traumas in our study were diagnosed because the use of the CT scan as primary screening tool most likely resulted in a higher detection frequency of "clinically silent" liver injuries, which presumably would not have been detected in the pre-CT era. However, the advantage of CT scan is not related only to the improved initial screening and assessment of organ injury at admission; it also allows reliable monitoring of liver trauma once NOM is selected. With increasing use of CT in NOM of liver trauma, there might be a concern that CT may miss associated injuries. A large cohort study composed of 833 patients with blunt liver and/or spleen injury revealed that CT scan missed associated abdominal injuries in only 1.1% of patients who had been selected for NOM [18]. Recent series of NOM demonstrated that this approach is a safe and effective treatment in selected patients with blunt traumas [19–22], as well as penetrating [23] liver traumas, with a success rate as high as 83–97%. In our study, the success rate for NOM was 96%, indicating that the selected treatment algorithm at admission was correctly chosen. The liver-specific success rate in ours and other studies [20, 22] was even higher, ranging from 96 to 100%. Unfortunately, the case number of patients with failed NOM in the present study was too low to define predictors of failure of NOM. Other investigators have suggested that the presence of intraperitoneal contrast extravasation and hematoperitoneum in six compartments on CT scan are associated with failure of NOM in initially hemodynamically stable patients with blunt liver trauma [24].

The central finding of the present study is that the change in liver trauma management resulted in a significant survival benefit for patients with blunt and penetrating liver trauma for the late period. The multivariate analysis revealed at least a 50% reduction in in-hospital mortality after 1996, which might be even 80% if the odds ratio is considered (Table 6). Furthermore, the analysis demonstrates that age, severity of hepatic, head (AIS head), and total injuries (ISS), and intubation status at admission were independent predictors for 24 h and in-hospital mortality. In accordance with other studies [25–27], these data indicate that not only the severity of liver trauma but also the severity of concomitant extrahepatic injuries has major impact on survival.

There is documented evidence that the use of early CT during trauma-room management has a significant impact on outcome [16, 17]. A recently published study showed that the early use of multi-slice CT resulted in a significant reduction in ventilation, ICU, and hospital days, and in the organ failure rate in patients with blunt major trauma [17]. Furthermore, the integration of whole-body CT into early management of patients with polytrauma was an independent predictor of favorable survival in a more recently published multicenter study [16].

Although randomized trials are lacking, there is accumulating evidence that damage control surgery is associated with improved outcome in liver trauma [28]. In our study, the introduction of damage control surgery is reflected by shorter operative times and more packing procedures in the later study period (Table 5). Perihepatic packing is intended to prevent acidosis, hypothermia, coagulopathy, and finally death from uncontrollable bleeding [7, 29, 30].

A large cohort study from the USA with a total of 1,842 liver injuries demonstrated a dramatic decrease in mortality over a 25-year observation period, which was mainly ascribed to the reduction of deaths from hepatic hemorrhage [31]. The significant decline in mortality was related to the improved outcome of major venous injuries. Similar to our observation, major changes in trauma management included the shift to NOM and the more frequent use of perihepatic packing and angiographic embolization in this study. Although detailed data on diagnostic tools and NOM were not reported, the authors suggest that NOM enabled major venous liver injuries to be treated without surgery. This is also confirmed by the present study, where a shift toward NOM has even been observed in high-grade liver injuries (grade III–V) (Table 3).

In conclusion, there has been a dramatic change in the diagnosis and management of hepatic trauma over the last quarter century, and this change is associated with improved survival. As shown by other studies, NOM of hepatic trauma is now the gold standard treatment in all hemodynamically stable patients. The policy of minimal intervention should be the rule for patients who require OM of liver trauma and concomitant injuries. The study indicates that early CT appears to be a mandatory element of trauma-room management. This concept should be considered in the planning and construction of trauma rooms.

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