Successful Nonoperative Management of the Most Severe Blunt Liver Injuries

A Multicenter Study of the Research Consortium of New England Centers for Trauma

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Hypothesis: Grade 4 and grade 5 blunt liver injuries can be safely treated by nonoperative management (NOM).

Design: Retrospective case series.

Setting: Eleven level I and level II trauma centers in New England.

Patients: Three hundred ninety-three adult patients with grade 4 or grade 5 blunt liver injury who were admitted between January 1, 2000, and January 31, 2010.

Main Outcome Measure: Failure of NOM (f-NOM), defined as the need for a delayed operation.

Results: One hundred thirty-one patients (33.3%) were operated on immediately, typically because of hemodynamic instability. Among 262 patients (66.7%) who were offered a trial of NOM, treatment failed in 23 patients (8.8%) (attributed to the liver in 17, with recurrent liver bleeding in 7 patients and biliary peritonitis in 10 patients). Multivariate analysis identified the following 2 independent predictors of f-NOM: systolic blood pressure on admission of 100 mm Hg or less and the presence of other abdominal organ injury. Failure of NOM was observed in 23% of patients with both independent predictors and in 4% of those with neither of the 2 independent predictors. No patients in the f-NOM group experienced life-threatening events because of f-NOM, and mortality was similar between patients with successful NOM (5.4%) and patients with f-NOM (8.7%) ($P = .52$). Among patients with successful NOM, liver-specific complications developed in 10.0% and were managed definitively without major sequelae.

Conclusions: Nonoperative management was offered safely in two-thirds of grade 4 and grade 5 blunt liver injuries, with a 91.3% success rate. Only 6.5% of patients with NOM required a delayed operation because of liver-specific issues, and none experienced life-threatening complications because of the delay.

Arch Surg. 2012;147(5):423-428

During the last decades, nonoperative management (NOM) of blunt liver injuries (BLIs) has become the standard of care for hemodynamically stable patients, who account for approximately 85% of all those with blunt hepatic trauma.[1-5]

See Invited Critique at end of article

With increasing experience, even severe BLIs have been managed by NOM. The splenic paradigm has shown that the literature offered an overenthusiastic picture about NOM success across all grades. Because the few high-grade splenic injuries were often diluted within the many low-grade injuries, the overall high success rates of NOM were misleadingly perceived as applicable to all grades.[6] A multicenter study[7] from our Research Consortium of New England Centers for Trauma (ReCONECT) group in 2010 showed that 38% of grade 4 and grade 5 splenic injuries with NOM eventually failed NOM. It also documented that 64% of all high-grade injuries required splenectomy emergently or after failed NOM.

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Anecdotal experience shows that severe BLIs are more hemostatic than severe splenic injuries. In a study[2] of 206 pa-

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Table 1. Liver Injury Grading Using the American Association for the Surgery of Trauma Organ Injury Scale[11]

Variable	Liver Injury Description[a]	Abbreviated Injury Scale Score, 1990 Revision
	Grade 1	
Hematoma	Subcapsular and <10% of surface area	2
Laceration	Capsular tear and parenchymal depth <1 cm	2
	Grade 2	
Hematoma	Subcapsular and 10%-50% of surface area or intraparenchymal and diameter <10 cm	2
Laceration	Parenchymal depth 1-3 cm and length <10 cm	2
	Grade 3	
Hematoma	Subcapsular and >50% of surface area or expanding, or ruptured subcapsular or parenchymal hematoma; or intraparenchymal hematoma >10 cm or expanding	3
Laceration	Parenchymal depth >3 cm	3
	Grade 4	
Laceration	Parenchymal disruption involving 25%-75% of hepatic lobe or 1-3 Couinaud segments in a single lobe	4
	Grade 5	
Laceration	Parenchymal disruption involving >75% of hepatic lobe or >3 Couinaud segments in a single lobe	5
Vascular	Juxtahepatic venous injuries (ie, retrohepatic vena cava or central major hepatic veins)	5
	Grade 6	
Vascular	Hepatic avulsion	6

[a] Advance 1 grade for multiple injuries to the same organ, up to grade 3.

tients, successful NOM of the liver was 17% higher than successful NOM of the spleen. To date, the only study[8] referring exclusively to high-grade liver injuries reports successful NOM in 41% of patients but is limited by few grade 5 injuries (10% of the entire population).

The ReCONECT group has combined the collective experience of multiple trauma centers to increase the sample size for injuries of low frequency.[9,10] The objective of the present study was to determine the rates and predictors of failure of NOM (f-NOM) in patients with grade 4 and grade 5 BLIs. We hypothesized that such high-grade BLIs can be safely managed by NOM.

METHODS

PATIENTS

We retrospectively included all adult patients with a grade 4 or grade 5 BLI who were admitted between January 1, 2000, and January 31, 2010, to 11 trauma centers in New England. Grading was based on computed tomography (CT) findings and according to the American Association for the Surgery of Trauma Organ Injury Scale[11] (**Table 1**). For patients who were taken to the operating room and given a different intraoperative grade than that assigned by CT, we recorded the intraoperative grade. All centers are verified by the American College of Surgeons Committee on Trauma as level I (9 centers) or level II (2 centers) trauma centers. Patients younger than 15 years, patients who received an urgent operation at an outside hospital, and patients who were dead at the scene or on arrival were excluded. Similarly, patients with grade 6 injury (liver avulsion) were not included because such patients rarely arrive at the hospital alive, and if they do, they usually die within a few hours.

DEFINITIONS

Patients were categorized as receiving NOM or an immediate operation (IO). Hemodynamic instability and signs of peritonitis were indications for IO. Nonoperative management was defined by a clear note in the medical record committing the patient to NOM or by the fact that an operation was booked later than 3 hours after the diagnosis of BLI. The decision to use 3 hours as the threshold for NOM definition was selected by consensus based on the infrastructure of the participating centers, which typically allowed for expeditious transfer to the operating room. We also wanted to account for patients with complex multiple trauma who spent an initial period of active resuscitation and diagnostic evaluation before a final decision was made about NOM vs IO.

Failure of NOM was defined as the need for surgery after a trial of NOM or as death from BLI during NOM. Success of NOM (s-NOM) occurred if a patient did not receive an abdominal operation during the index hospital stay and did not succumb to the liver injury.

DATA AND OUTCOMES

We collected data on demographics, Injury Severity Score, liver injury grade (4 vs 5), associated injuries, and mechanism of blunt trauma (motor vehicle–related crash, fall, assault, or other). We also recorded admission hemodynamics, CT findings, and the presence of free abdominal blood on CT (recorded as diffuse or only around the liver). We also noted the following: type of management (NOM vs IO), indication for operative intervention, operative procedure, and operative findings, as well as intensive care unit and hospital stay and morbidity and mortality. The main outcome measure was f-NOM. It was further classified as liver-specific f-NOM, indicating that an operation was performed to treat bleeding, leak, or infection from the liver injury, or as non–liver-specific f-NOM, indicating that an operation was performed to treat other abdominal organ injury (eg, bleeding from the spleen).

STATISTICAL ANALYSIS

Patients who received NOM vs IO were compared. In addition, patients having f-NOM were compared with patients having s-NOM. Selected continuous variables were dichotomized across clinically meaningful values: age was dichotomized at 55 years, Injury Severity Score at 25, systolic blood pressure on admission at 100 mm Hg, heart rate on admission at 100 beats/min, and hematocrit on admission at 30%. Continuous variables were summarized using mean (SD) values and were compared using 2-sample *t* test or were summarized using median values (interquartile ranges) and compared using the Wilcoxon rank sum test. Categorical variables (reported as counts and proportions) were compared using the χ^2 test or Fisher exact test. Logistic regression analysis was performed to identify independent predictors of f-NOM significant at .05. Odds ratios (95% CIs) were reported for each predictor. The incidence of f-NOM based on different combinations of independent predictors of f-NOM was examined. $P \leq .05$ indicated statistical significance. Commercially available software (SAS version 9.2; SAS Institute, Inc) was used for all analyses. The study was approved by the institutional review boards of all participating centers.

RESULTS

During the 10-year study period, 393 adult patients with grade 4 and grade 5 BLI were included at 11 ReCONECT centers that participated in this study. One hundred thirty-one patients (33.3%) underwent an IO, while 262 patients (66.7%) were offered a trial of NOM. One hundred five of 131 patients (80.2%) underwent damage control surgery with packing of the liver.

The mean (SD) age of the study population was 33 (16) years (median age, 28 years; age range, 15-95 years), and the mean (SD) Injury Severity Score was 32 (14) (median, 29; range, 4-75). Fifty-four percent of patients were male, and 43.8% of patients had other abdominal organ injury, 13.9% had a brain injury, and 31.8% had major fracture. The mean (SD) intensive care unit stay for 324 patients who required critical care was 9 (17) days (median, 3 days; range, 0-164 days), and the mean (SD) hospital stay among the total population was 16 (22) days (median, 8 days; range, 1-204 days). Mortality was 21.4% (84 patients), including 60 patients who died within 24 hours, 11 patients who died between the second and seventh days, and 13 patients who died later.

NOM vs IO

Except for age, heart rate on admission, major fracture, and other extra-abdominal injury, all recorded variables were significantly different between patients receiving NOM vs IO. Not surprisingly, morbidity and mortality were higher among patients undergoing IO. The intensive care unit stays and hospital stays were similar between the 2 groups when all patients were evaluated but were longer among patients undergoing IO when only survivors were analyzed (**Table 2**).

Table 2. Comparison of Patients Who Received an Immediate Operation (IO) vs Patients Who Were Offered a Trial of Nonoperative Management (NOM)

Variable	IO (n = 131)	NOM (n = 262)	*P* Value
Age, mean (SD), y	33 (15)	33 (17)	.88
Male sex, No. (%)	86 (65.6)	125 (47.7)	.003
Mechanism of blunt trauma, No. (%)[a]			
Motor vehicle–related crash	108 (82.4)	213 (81.3)	.02
Fall	6 (4.6)	26 (10.0)	
Assault	7 (5.3)	2 (0.8)	
Injury Severity Score, mean (SD)	41 (15)	27 (11)	<.001
Systolic blood pressure on admission, mean (SD), mm Hg	102 (32)	122 (25)	<.001
Heart rate on admission, mean (SD), beats/min	103 (33)	97 (21)	.09
Hematocrit on admission, mean (SD), %	31 (7)	37 (26)	<.001
Glasgow Coma Scale score, mean (SD)	8 (6)	13 (4)	<.001
Brain injury, No. (%)	27 (20.6)	28 (10.7)	.008
Major fracture, No. (%)	43 (32.8)	82 (31.3)	.76
Other abdominal organ injury, No. (%)	45 (34.4)	127 (47.7)	.008
Other extra-abdominal injury, No. (%)	103 (78.6)	216 (82.4)	.36
CT liver injury grade, No. (%)			
4	79 (60.3)	234 (89.3)	<.001
5	52 (39.7)	28 (10.7)	
Contrast extravasation on CT, No. (%) (n = 228)	28 (21.4)	70 (26.7)	<.001
Presence of free abdominal blood on CT, No. (%)			
No blood or only around the liver	77 (58.8)	79 (30.2)	<.001
Diffuse	54 (41.2)	183 (69.8)	
Morbidity, No. (%)	112 (85.5)	114 (43.5)	<.001
Mortality, No. (%)	69 (52.7)	15 (5.7)	<.001
Hospital stay, mean (SD), d	17 (24)	16 (21)	.62
ICU stay, mean (SD), d	5 (9)	24 (25)	.30
Hospital stay among survivors, mean (SD), d	33 (26)	14 (16)	<.001
ICU stay among survivors, mean (SD), d	20 (19)	7 (12)	<.001

Abbreviations: CT, computed tomography; ICU, intensive care unit.
[a]Data not shown for patients with other mechanisms of blunt trauma.

s-NOM vs f-NOM

Nonoperative management failed in 23 of 262 patients (8.8%) The rates of failure were 8.1% among patients with grade 4 BLI and 14.3% among patients with grade 5 BLI ($P = .28$). Patients with f-NOM had lower systolic blood pressure on admission, longer intensive care unit stay and hospital stay, and higher rates of other abdominal organ injury, hepatic angiography, and morbidity (**Table 3**). Of 23 patients with f-NOM, 17 failed NOM because of liver-specific reasons (7 due to recurrent liver bleeding and 10 due to biliary peritonitis). Of 7 patients with recurrent liver bleeding, 5 received packing of the liver, and 2 underwent nonanatomical resections. The remaining 6 patients with f-NOM had non–liver-specific issues (small bowel injury in 3, colon injury in 1, duodenal injury in 1, and gallbladder necrosis in 1). Therefore, liver-specific f-NOM was 6.5%.

Seventeen patients with liver-specific f-NOM underwent surgery a mean (SD) of 6 (7) days (range, 0-26 days) after admission; the mean (SD) values were 2 (2) days (range, 0-17 days) after admission for those with recurrent liver bleeding and 9 (8) days (range, 1-26 days) af-

Table 3. Comparison of Patients With Success of Nonoperative Management (s-NOM) vs Patients With Failure of Nonoperative Management (f-NOM)

Variable	s-NOM (n = 239)	f-NOM (n = 23)	*P* Value
Age			
Mean (SD), y	33 (17)	31 (13)	.41
≥55 y, No. (%)	26 (10.9)	1 (4.3)	.32
Male sex, No. (%)	109 (45.6)	16 (69.6)	.09
Mechanism of blunt trauma, No. (%)			
Motor vehicle–related crash	194 (81.2)	19 (82.6)[a]	.98
Fall	24 (10.0)	2 (8.7)	
Assault	2 (0.8)	0	
Other	18 (7.5)	2 (8.7)	
Injury Severity Score			
Mean (SD)	27 (11)	29 (7)	.15
>25, No. (%)	122 (51.0)	15 (65.2)	.20
Systolic blood pressure on admission			
Mean (SD), mm Hg	124 (25)	110 (21)	.007
≤100 mm Hg, No. (%)	40 (16.7)	9 (39.1)	.01
Heart rate on admission			
Mean (SD), beats/min	97 (21)	97 (21)	.95
>100 beats/min, No. (%)	103 (43.1)	9 (39.1)	.68
Hematocrit on admission			
Mean (SD), %	37 (27)	36 (6)	.51
≤30%, No. (%)	43 (18.0)	3 (13.0)	.53
Glasgow Coma Scale score, mean (SD)	13 (4)	14 (3)	.5
Brain injury, No. (%)	26 (10.9)	2 (8.7)	.75
Major fracture, No. (%)	75 (31.4)	7 (30.4)	.93
Other abdominal organ injury, No. (%)	110 (46.0)	17 (73.9)	.01
Other extra-abdominal injury, No. (%)	194 (81.2)	22 (95.7)	.08
CT liver injury grade, No. (%)			
4	215 (90.0)	19 (82.6)	.28
5	24 (10.0)	4 (17.4)	
Contrast extravasation on CT, No. (%) (n = 188)	61 (25.5)	9 (39.1)	.34
Presence of free abdominal blood on CT, No. (%)			
No blood or only around the liver	76 (31.8)	3 (13.0)	.06
Diffuse	163 (68.2)	20 (87.0)	
Morbidity, No. (%)	91 (38.1)	23 (100.0)	<.001
Mortality, No. (%)	13 (5.4)	2 (8.7)	.52
Hospital stay, mean (SD), d	13 (15)	41 (46)	.009
ICU stay, mean (SD), d	6 (11)	29 (41)	.02
Hospital stay among survivors, mean (SD), d	13 (13)	32 (29)	.008
ICU stay among survivors, mean (SD), d	6 (9)	21 (27)	.02

Abbreviations: CT, computed tomography; ICU, intensive care unit.
[a]The mechanism of injury was unknown for 1 patient.

ter admission for those with biliary peritonitis. All but 2 of 7 patients with f-NOM who required surgery for recurrent liver bleeding underwent an exploratory laparotomy within 24 hours of admission. No liver-specific morbidity was recorded as a direct consequence of f-NOM, and none of these patients died.

The following 2 independent predictors of f-NOM were identified: systolic blood pressure on admission of 100 mm Hg or less (odds ratio, 2.70; 95% CI, 1.07-6.77) and the presence of other abdominal organ injury (odds ratio, 2.92; 95% CI, 1.10-7.76) (*P*=.03 for both). If both independent predictors were present, 22.6% of individuals had f-NOM, as opposed to 10.6% if 1 independent predictor was present and 3.5% if neither of the 2 independent predictors was present. The negative predictive value for the absence of both independent predictors was 96.5%.

INTERVENTIONS

Of 262 patients treated with NOM, 94 (35.9%) received hepatic angiography, and 65 (24.8%) underwent embolization. Among 239 patients with s-NOM, 79 (33.1%) received hepatic angiography, and 55 (23.0%) underwent embolization. Three of 55 patients (5.5%) developed recurrent liver bleeding, which was controlled by reembolization in 2 and ceased spontaneously in 1. Of 7 patients who failed NOM due to recurrent liver bleeding, 5 received hepatic angiography, and 4 underwent embolization before surgery. The success rate of embolization (including reembolization) was 93.2% (55 of 59).

Endoscopic retrograde cholangiopancreatography (ERCP) was performed in 16 patients with NOM for biliary leaks. Three of them failed NOM. An additional 5 patients received ERCP after IO. Percutaneous drainage of abdominal collections was performed in 14 patients with NOM and in 6 patients with IO.

Overall, 39.2% (154 of 393) of the total study population underwent surgery, including 23 patients with f-NOM and 131 patients with IO. Among them, 63.7% had grade 4 BLI, and 36.3% had grade 5 BLI. Two patients with f-NOM underwent laparoscopy, 1 for biliary peritonitis and 1 for small bowel injury; all other patients underwent exploratory laparotomy.

COMMENT

The shift toward NOM of BLI has been profound during the last few decades. From the early articles advocating near-mandatory operation for all liver injuries[12,13] to recent recommendations of treating most BLIs with NOM,[14] there is clearly a major change in the standard of care. As usually happens with new methods, the rapidly growing enthusiasm for NOM of solid visceral injuries allowed an overstatement of its scope and outcomes. For example, the unchecked optimism about the positive outcomes of NOM on the injured spleen is balanced by recent evidence showing that more than one-third of severe splenic injuries fail NOM.[7]

The liver is known to respond well to NOM.[1,2,4,8,14-19] However, as occurred with the spleen, the data describing high nonoperative success rates included primarily low-grade liver injuries. Severe injuries of the liver were typically treated with an operation. For example, among 128 patients with grade 4 BLIs and 31 patients with grade 5 BLIs described by Kozar et al,[17] only 40% with grade 4 injury and 4% with grade 5 injury were offered NOM. In 1996, a multicenter study[20] from the Western Trauma Association demonstrated few NOM failures. Of 404 patients having BLIs treated with NOM, 58 had grade 4 or grade 5 injuries. There were 6 NOM failures (1.5%), and only 3 of them were specific to the liver. The article did not specify the grade of injury in these 6 patients or the number of patients with grade 4 or grade 5 injuries managed with IO. In a study[14] of 55 patients having BLIs with NOM at a hospital in Los Angeles, California, 8 patients failed NOM (14.5%), although none because of liver-specific reasons. Notably, 6 of 8 failures were among patients with liver injury grade 3 or higher. Other groups have reported on high-grade liver injuries but focused on operations only[5] or did not distinguish between patients who were operated on immediately and those who were operated on after NOM had failed.[8]

Our consortium of 11 trauma centers in New England focused exclusively on grade 4 and grade 5 BLIs. One-third of patients herein underwent IO, and the remaining two-thirds were offered a trial NOM. More than 90% of patients receiving NOM were discharged without a midline laparotomy. The liver was the specific cause of NOM failure in 6.5% of patients. Notably, 7 of 17 patients with liver-specific f-NOM had recurrent liver bleeding, and the remaining 10 had biliary peritonitis. None of 7 patients with recurrent liver bleeding experienced complications that could be attributed to f-NOM, and none of them died.

The high rate of s-NOM herein was in part because of bleeding control via angiographic embolization. One-quarter of patients receiving NOM underwent embolization, with a 93.2% success rate for control of recurrent liver bleeding. Other studies[21-23] have shown that liver embolization for trauma is safe and effectively stops bleeding. In our population, most angiographies were performed within the first 24 hours of admission, attesting to the fact that embolization was an important element of the NOM strategy.

Additional interventions, such as ERCP, stenting, or percutaneous drainage of abdominal collections, have been recommended as effective tools to control bile leaks following severe liver trauma.[24] Laparoscopic drainage of biliary collections has been used to ameliorate severe inflammatory response in selected patients with NOM who remain tachycardic and febrile 3 to 5 days after injury.[25] In our study, we used ERCP and percutaneous drainage of abdominal collections in 6% and 5% of the population, respectively.

Our multi-institutional collaboration enhances the sample size of an uncommon injury but affects the ability to collect important details, particularly in view of its retrospective design. Therefore, precise information about decision making is missing. We set an arbitrary number of hours after admission, beyond which an operation was offered because of f-NOM. It is possible that some of these patients were never offered NOM but deteriorated during the period of evaluation. In this context, "failure" of NOM should not be attributed to the inability of trauma surgeons to triage patients appropriately but rather to the natural history of some injuries, which continue to bleed, despite optimal management. We observed no patients who were clearly harmed by f-NOM. Although such patients undoubtedly exist, f-NOM does not seem to subject patients to increased risk of complications and death. Of course, close observation and monitoring of such severe injuries are required before consideration of NOM. Finally, we could make no statements about several issues that are widely debated and continue to remain without answers: How long should these patients remain in the hospital? When should they be allowed to return to strenuous activities? What is the role of routine successive imaging? Our study was not designed to answer these questions.

In summary, grade 4 and grade 5 liver injuries respond well to NOM. In contrast to splenic injuries of similar grades, many of which are destined to fail NOM,[7] most severe BLIs can be managed without an operation. High-grade liver injuries seem to behave in a dichotomous way: they bleed immediately and dramatically and are in obvious need of surgical intervention, or they do not bleed and can be managed reliably by NOM, with a low likelihood of subsequent bleeding. There is little reason to intervene surgically in those hemodynamically stable patients, no matter how striking the CT image may be. In this multicenter study, 66.7% of patients with grade 4 or grade 5 BLI were offered NOM, which was successful in 91.3% of them. Only 6.5% of patients with f-NOM failed because of their liver injury.

Accepted for Publication: December 20, 2011.
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Financial Disclosure: None reported.
Previous Presentation: This paper was presented at the 92nd Annual Meeting of the New England Surgical Society; September 23, 2011; Bretton Woods, New Hampshire; and is published after peer review and revision.

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INVITED CRITIQUE

Nonoperative Management of Major Liver Trauma—When Failure May Be a Success

In the 1980s, nonoperative management (NOM) of liver injuries began to come of age. Stable liver injuries could be managed with a period of observation. I vividly recall a discussion in a publication where prominent trauma surgeons lamented deaths they had contributed to by operating on minimally bleeding hepatic lacerations in stable patients. All concluded that you should not poke a skunk.

Major liver trauma continues to be a lethal injury. In this issue of the *Archives*, the Research Consortium of New England Centers for Trauma group reviews the success of operative management and NOM in 393 patients with grade 4 or grade 5 blunt liver injury during a 10-year period.[1] Important and practical lessons can be gleaned from this study.

Major liver injuries are unusual. If distributed equally, each trauma center would see 3 or 4 high-grade liver injuries yearly, making preparation and planning critical. van der Wilden et al[1] did not describe the plan of care, but this is a circumstance in which 2 trained trauma surgeons are needed in the operating room (OR) to maximize survival.