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Nonoperative Management of Blunt Hepatic Trauma Is the Treatment of Choice for Hemodynamically Stable Patients

Results of a Prospective Trial

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Background
A number of retrospective studies recently have been published concerning nonoperative management of minor liver injuries, with cumulative success rates greater than 95%. However, no prospective analysis that involves a large number of higher grade injuries has been reported. The current study was conducted to evaluate the safety of nonoperative management of blunt hepatic trauma in hemodynamically stable patients regardless of injury severity.

Methods
Over a 22-month period, patients with blunt hepatic injury were evaluated prospectively. Unstable patients underwent laparotomies, and stable patients had abdominal computed tomography (CT) scans. Those with nonhepatic operative indications underwent exploration, and the remainder were managed nonoperatively in the trauma intensive care unit. This group was compared with a hemodynamically matched operated cohort of blunt hepatic trauma patients (control subjects) who had been prospectively analyzed.

Results
One hundred thirty-six patients had blunt hepatic trauma. Twenty-four (18%) underwent emergent exploration. Of the remaining 112 patients, 12 (11%) failed observation and underwent celiotomy—5 were liver-related failures (5%) and 7 were nonliver related (6%). Liver related failure rates for CT grades I through V were 20%, 3%, 3%, 0%, and 12%, respectively, and rates according to hemoperitoneum were 2% for minimal, 6% for moderate, and 7% for large. The remaining 100 patients were successfully treated without operation—30% had minor injuries (grades I–II) and 70% had major (grades III–V) injuries. There were no differences in admission characteristics between nonoperative success or failures, except admission systolic blood pressure (127 *vs.* 104; $p < 0.04$). Comparing the nonoperative group to the control group, there were no differences in admission hemodynamics or hospital length of stay, but nonoperative patients had significantly fewer blood transfusions (1.9 *vs.* 4.0 units; $p < 0.02$) and fewer abdominal complications (3% *vs.* 11%; $p < 0.04$).

Conclusions

Nonoperative management is safe for hemodynamically stable patients with blunt hepatic injury, regardless of injury severity. There are fewer abdominal complications and less transfusions when compared with a matched cohort of operated patients. Based on admission characteristics or CT scan, it is not possible to predict failures; therefore, intensive care unit monitoring is necessary.

Although the liver is the abdominal organ most commonly injured after blunt trauma, the majority of injuries are relatively minor. Operative management of these patients often results in a nontherapeutic exploration because the liver usually has stopped bleeding. Operative management of the more severe liver injuries, however, is associated with significant morbidity and mortality.

Over the past decade, a number of retrospective reports have demonstrated that nonoperative management of stable patients with minor hepatic injuries is safe.[1-10] However, relatively few major hepatic injuries were included in these reports. It had been thought that spontaneous hemostasis after parenchymal disruption occurred infrequently with significant liver injuries.[11] This continued hemorrhage could contribute to prolonged nonresuscitated hemorrhagic shock, increased transfusion requirements, and ultimately, death from sepsis and multiple-organ failure.

It was our hypothesis that the most important factor that should determine whether to operate on the injured liver was the presence or absence of hemodynamic stability. We designed a prospective study to answer the following questions

1. Is nonoperative management feasible for all grades of blunt hepatic injury?
2. Can patients who ultimately fail nonoperative management be predicted?

To address these questions, hemodynamically stable patients with blunt hepatic injury and no other indications for celiotomy were treated without operation. Because it is not practical to randomize patients between operative and nonoperative therapy, comparisons of morbidity, mortality, and transfusions were made with a similarly injured population that previously had been prospectively studied,[12] all of whom underwent celiotomy for blunt hepatic injury.

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MATERIALS AND METHODS

All victims of blunt trauma admitted to the Presley Regional Trauma Center over a 22-month period ending October 1994 were potential study candidates. Patients with blunt abdominal trauma who were hemodynamically unstable underwent diagnostic peritoneal lavage. Emergent celiotomy was performed if 20 mL of blood was aspirated. Patients who were hemodynamically stable underwent abdominal computed tomography (CT).

Standard protocols of resuscitation established by the American College of Surgeons' Committee on Trauma were used. Crystalloids were used to re-establish circulation, and blood was transfused if there was an inadequate response to crystalloid or if there was obvious ongoing hemorrhage.

After resuscitation, patients were administered 500 to 750 mL of oral contrast (2% barium suspension) via mouth or nasogastric tube. In addition to the oral contrast, all patients received intravenous contrast (iohexol; approximately 150 mL). Axial scans were performed on a GE HiSpeed Advantage Helical Scanner (General Electric, Milwaukee, WI). Liver injuries were graded based on the appearance on the CT scan according to the Hepatic Injury Scale established by the American Association for the Surgery of Trauma.[13] Briefly, this is an anatomic description of injury scaled from I to VI, representing the least to most severe injury. Grade I includes a small subcapsular hematoma or superficial laceration; grade II is a subcapsular hematoma covering 10% to 50% of surface area or a 1- to 3-cm laceration that is less than 10 cm in length; grade III is a large (>50%) or ruptured subcapsular hematoma, an intraparenchymal hematoma > 2 cm, or a laceration > 3 cm in depth; grade IV is a ruptured intraparenchymal hematoma or lobar parenchymal disruption involving 25% to 50% of the lobe; grade V is lobar parenchymal disruption > 50% or juxtahepatic venous injuries; and grade VI is hepatic avulsion. The amount of hemoperitoneum was quantitated as follows: minimal—perihepatic blood in the subphrenic or subhepatic space (approximately 250 mL); moderate—perihepatic plus blood along either or both paracolic gutters (250–500 mL); large—perihepatic, paracolic gutter, and blood accumulating in the pelvis (>500 mL). Follow-up CT scans were obtained at 2 to 5 days and weekly until hospital discharge or significant healing was documented. Thereafter, scans were obtained as clinically indicated. Patients had hepato-iminodiacetic acid (99 m Tc-dimethyl aminodracetric acid) scans 5 to 7 days after injury to assess bile leakage. A biloma was defined as any bile collection, either intrahepatic or extrahepatic.

Assessment of hemodynamic stability was occasionally difficult in the patient with multiple injuries. Routine vital signs, serum lactate, and base excess were used. On admission, patients either had systolic blood pressure greater than 90 mm Hg, lactate less than 5 mmol/L, or base excess greater than −5 meq/L, or all quickly improved after crystalloid administration. In equivocal cases, an oximetric pulmonary artery catheter was placed. Transfusion requirements were estimated according to the following general scale: femur fracture, 2 units; tibia fracture, 1 unit; upper extremity fracture, 1 unit; multiple facial fractures, 1 unit; pelvic rami fractures, 2 units; multiple rib fractures with hemothorax, 2 units; and splenic injury, 2 units. One unit was added for each open fracture. Patients with unstable pelvic fractures involving the posterior elements underwent emergent external fixator placement followed by angiography, if necessary. Serial hematocrits were drawn every 6 hours for 4 days or until the patient left the trauma intensive care unit.

Analysis of morbidity included presence of biloma, perihepatic abscess, hepatic artery pseudoaneurysm, hepatic artery—portal vein arteriovenous fistula, and length of hospitalization. Patients were classified as having a liver-related failure if they required hepatorrhaphy because of development of hemodynamic instability, had a continued falling hematocrit that was unexplained by associated injuries, or had worsening appearance on follow-up CT scan. Patients were classified as having a nonliver-related failure if they underwent celiotomy based on associated injuries and no hepatorrhaphy was performed at the time of operation. Transfusions were recorded as either admission or total transfusions. Admission transfusions included units transfused during resuscitation, and total transfusions included all units given within the first 48 hours from admission, including any blood given while a patient underwent either orthopaedic or neurosurgical procedures.

The patients from the current study of nonoperative management were compared with a control population from a prior prospective trial at our institution.[12] Those patients had blunt liver injuries, and all received immediate operation based primarily on diagnostic peritoneal lavage findings. Only the cohort of patients who were hemodynamically stable were included. This group was further analyzed according to associated intra-abdominal injuries. Patients with hollow viscus, pancreatic, diaphragmatic, or significant splenic injuries would not be considered candidates for nonoperative management and were excluded. The Hepatic Injury Grade for the control subjects who underwent operation was based on operative grading, regardless of whether the patient had a preoperative CT scan. Admission transfusions were defined as blood given preoperatively, and total transfusions included all blood given within the perioperative (first 48 hours) period. The analysis of morbidity was performed as previously mentioned.

Discrete variables were analyzed using chi square analysis or the Fisher exact test. Continuous variables were analyzed using an unpaired t test. All differences at the $p < 0.05$ level were considered significant.

RESULTS

The total study population consisted of 136 patients. The mechanisms of injury were motor vehicle accident in 84%, automoblie-pedestrian accident in 7%, assault in 5%, motorcycle accident in 2%, and all-terrain vehicle accident in 2%. Twenty-four patients (18%) underwent emergent celiotomies because they had other abdominal injuries seen on abdominal CT (14 patients) or hemodynamic instability from intra-abdominal hemorrhage (10 patients). Mean Injury Severity Score (ISS) for this group of patients was 34. Transfusion requirements for these patients were high—13.6 units within the first 48 hours. There were three early deaths (13%) from hemorrhage, and nine deaths overall (38%). Five of these were due to severe brain injury, and one was from pulmonary sepsis and multiple-organ failure. Excluding the early deaths, the abdominal septic complication rate was 14%.

The remaining 112 patients with liver injury (82%) were hemodynamically stable, had no obvious indication for celiotomy, and were initially managed nonoperatively. The mean age was 33 years, ISS was 22, and 53% were male. The mean admission systolic blood pressure was 123 mm Hg, serum lactate was 4.5 mmol/L, and base excess was −2.6 meq/L. The distribution of hepatic injury grade according to the Organ Injury Scale of the American Association for the Surgery of Trauma was as follows: grade I, 5 (5%); grade II, 30 (27%); grade III, 34 (30%); grade IV, 26 (23%); and grade V, 17 (15%). The mean total transfusion requirements were 2.9 units. Overall mortality was 9% (10 patients)—six deaths were due to severe brain injury, and four were due to multiple-organ failure (all from severe pulmonary injury followed by pneumonia).

Quantity of hemoperitoneum is shown in Table 1. In general, the amount of blood in the peritoneal cavity increased with increasing severity of liver injury. Overall, 45% had a minimal amount, 31% had a moderate

Table 1. QUANTITY HEMOPERITONEUM BY HEPATIC INJURY GRADE*

	I	II	III	IV	V
Minimal	80	70	53	19	12
Moderate	—	13	29	50	47
Large	20	17	18	31	41

* Numbers are percentages within injury grade.

amount, and 24% had a large amount of hemoperitoneum.

Of the 112 patients initially treated without operation, 100 (nonoperative patients) were treated successfully (89%). Patient demographics, hemodynamics, and transfusion requirements are shown in Table 2. The majority had multiple-system injuries, with only 5% having isolated liver injuries. Fifteen percent had other abdominal injuries (spleen or kidney), 33% had closed head injury, and 20% had pelvic fractures. The most common associated injuries were long bone fractures, which occurred in 52%. Most were lower extremity fractures (63%), upper extremity fractures were found in 17%, and 20% had both.

Of the 12 failures (11%) of nonoperative management, five (5%) were liver related, and seven (6%) were not liver related (Table 3). Of the five patients with liver-related failures, four underwent laparotomy because of hemodynamic instability. One of these was a patient who suddenly became hypotensive on hospital day 11. She had ligation of a bleeding vessel and omental packing of her injury. The other three patients became unstable within 18 hours of admission, and all had hepatorrhaphy with omental packing. The remaining patient with liver-related failure remained hemodynamically stable, but had increased intraperitoneal blood on follow-up CT scan 36 hours after injury. She also had hepatorrhaphy with omental packing. Of the nonliver-related failures, five patients had significant associated abdominal injuries (two pancreas, one kidney, one duodenum, and one proper hepatic artery), and all underwent operations within 54 hours of admission. None of these patients required hepatorrhaphy at the time of abdominal exploration. The remaining two patients had severe brain injuries, and each became hemodynamically unstable during craniotomy. Both underwent emergent laparotomies, and both had nontherapeutic explorations.

One patient in the liver-related failure group had an abdominal septic complication (infected biloma, which was percutaneously drained). There were three infectious abdominal complications in the nonliver-related failure group—one was percutaneously drained and the others were operatively drained.

Overall liver related failure rates according to CT grades I through V were 20%, 3%, 3%, 0%, and 12%, respectively. Liver-related failure rates according to hemoperitoneum were 2% for minimal, 6% for moderate, and 7% for large. One patient in each group died—one from multiple-organ failure due to pulmonary sepsis (liver-related group), and the other from severe brain injury (nonliver-related group).

Patients successfully treated without operation were compared with the liver-related failure group to search for predictors of failure. There were no significant differences in age, ISS, lactate, base excess, or admission transfusion, although the patients with failure were younger (24 *vs.* 33 years) and had higher ISS (30 *vs.* 21). Admission systolic blood pressure was lower in the failure group (104 *vs.* 127 mm Hg; $p < 0.04$). Although the difference was statistically significant, it was not clinically relevant because all patients initially responded appropriately to crystalloid resuscitation. Thus, there was no reliable predictor of failure other than the ultimate development of hemodynamic instability.

Operated Controls

Out of 168 patients with blunt liver injury who previously were prospectively studied,[12] 84 (50%) were matched for injury severity to the nonoperative group (control subjects; Table 2). Groups were well matched relative to admission blood pressure, serum lactate, base excess, and admission transfusion requirements. Control ISS was higher (28 *vs.* 21; $p < 0.01$), which may reflect differences between Abbreviated Injury Score (AIS)-85

Table 2. CHARACTERISTICS OF VARIOUS PATIENT GROUPS

Patient Variable	Nonoperative	Control	p Value
N	100	84	
M/F	52/48	51/53	NS
Age (yrs)	33	28	0.01
Injury severity score	21	28	0.01
Systolic blood pressure (mm Hg)	127	130	NS
Lactate	4.5	3.1	0.03
Base excess	−2.3	−2.4	NS
Admission transfusion	0.2	0.1	NS
Total transfusion	1.9	4.0	0.02
Biloma (%)	20	17	NS
Abdominal complication (%)	3	11	0.04
Hospital length of stay	16	17	NS
Deaths (%)	8	5	NS

Table 3. NONLIVER RELATED AND LIVER RELATED FAILURES

Patient No.	Hepatic Injury Grade	Injury Severity Score	Hemoperitoneum	48-Hour Transfusions	Abdominal Complication	Associated Injuries
			Nonliver Related			
1	1	54	Large	12	Intra-abdominal abscess	Hepatic artery, spleen
2	1	34	Minimal	28	None	Brain
3	2	13	Minimal	6	Intra-abdominal abscess	Pancreas
4	4	35	Moderate	6	Intra-abdominal abscess	Pancreas, spleen
5	4	16	Large	6	None	Kidney
6	5	29	Large	1	None	Duodenum
7*	5	41	Large	14	None	Brain
			Liver Related			
1	1	34	Minimal	23	None	Gallbladder
2	2	29	Moderate	5	None	None
3†	3	50	Large	8	None	None
4	5	34	Moderate	2	None	None
5	5	21	Large	29	Intra-abdominal abscess	None

* Death from severe brain injury.
† Death from pulmonary sepsis.

and AIS-90 (used to calculate ISS for control and nonoperative groups, respectively). In addition to the different scales that were used, there also was a difference in the maximum AIS between observed patients and those who underwent operation. The highest AIS assigned to a liver injury that was managed nonoperatively was 2, whereas the highest AIS assigned to an operated liver was 5. Operative grading of liver injuries for control subjects demonstrated 19% grade I, 21% grade II, 42% grade III, 11% grade IV, and 7% grade V.

Group Comparisons

Hepatic injuries were classified as either minor (grades I–II) or major (grades III–V). Comparisons between the study populations (nonoperative and control) are shown in Table 4. Among those with minor liver injuries, the control group had a significantly higher ISS, but otherwise, the groups are well matched. Transfusions for control subjects were slightly higher than those for the nonoperative group, but the difference was not statistically significant. Abdominal septic complications in this population with minor liver injury were 6% for control subjects and 0% for the nonoperative group. Mortality was 10% in the nonoperative group (one pulmonary, two severe brain injury) and 6% in the control group (both pulmonary sepsis); none were liver-related deaths.

Among those with major liver injuries, the groups are well matched relative to severity of shock on hospital admission. Admission transfusions were equal. However, those who underwent operations for the more severe liver injuries required significantly more transfusions than those managed without operation (5.8 units *vs.* 2.1; $p < 0.01$). The incidence of biloma was similar between groups. Abdominal complications were more frequent in the control group (14% *vs.* 4%), although the difference did not reach statistical significance ($p < .09$). Overall mortality also was similar, and each group had one liver-related death.

Complications

Seventy patients underwent hepato-iminodiacetic acid scans (70% of nonoperative group), and 14 (20%) had biloma. One of these patients was symptomatic and was percutaneously drained. The remainder were not symptomatic and resolved spontaneously. There were two other abdominal complications in the nonoperative group—both were from vascular injuries. One had a small hepatic artery pseudoaneurysm (grade V injury), which was successfully embolized; the other patient had an hepatic artery-portal vein fistula (grade IV injury), which also was successfully embolized. Thus, the abdominal complication rate in nonoperative patients requiring intervention was 3%. This was significantly less than the control groups' abdominal complication rate of 11% (1 pseudoaneurysm, 11 perihepatic abscesses; $p < 0.04$).

There was one death in the nonoperative group, which

Table 4. COMPARISON OF MINOR AND MAJOR LIVER INJURIES BETWEEN SUCCESSFUL NONOPERATIVE AND OPERATED CONTROL PATIENTS

	Minor (Grades I–II)		Major (Grades III–V)	
Patient Variable	Nonoperative	Control	Nonoperative	Control
N	30	34	70	50
M/F	16/14	18/16	36/34	33/17
Age	32	26	34	29
Injury severity score	23	28	21*	29*
Systolic blood pressure (mm Hg)	127	127	127	122
Lactate	5.0	3.2	4.4	3.1
Base excess	−2.7	−3.4	−2.2	−2.6
Admission transfusion	0.1	0.1	0.2	0.3
48-hour transfusion	1.2	1.4	2.2*	5.8*
Biloma (%)	3	0	26	27
Abdominal Complications (%)	0	6	4	14
Hospital length of stay	20	16	15	17
Deaths (%)	10	6	7	4

* $p < 0.01$.

may be considered liver related. This occurred in an 80-year-old man with a grade V liver injury with a large amount of peritoneal blood. He also had a significant pelvic fracture with retroperitoneal hematoma. He received a total of 6 units of blood, and follow-up CT scan did not demonstrate evidence of further intraperitoneal hemorrhage. He ultimately died of sepsis and multiple-organ failure. There also was one liver-related death in the control group. This patient developed hepatic artery pseudoaneurysm with hemobilia after his initial operation for a grade III injury and died during attempted hepatic resection.

Of the patients successfully managed without operation, no patient had worsening of the liver injury on follow-up CT scan, and 15% demonstrated complete resolution before hospital discharge. Nine patients did not have follow-up scans, and all were discharged without complications. The remaining patients in the nonoperative group had either total or near total resolution of their liver injury at the time of their last CT scan. The longest interval from injury to healing was 13 months, with most livers healing within 3 to 4 months.

DISCUSSION

The liver is the organ most commonly injured after abdominal trauma. Management schemes for significant hepatic injury have changed throughout the years, all with the primary goal of reducing morbidity and mortality from hemorrhagic shock and sepsis. Fortunately, the majority of blunt liver injuries are not severe and are amenable to simple operative techniques, such as cautery, topical hemostatic agents, or ligation of superficial vessels. These injuries account for 70% to 90% of hepatic wounds.[12,14–16] In fact, many of these wounds have stopped bleeding at the time of celiotomy. The remaining 10% to 30% of injuries, however, challenge even the most experienced surgeons. There are a variety of operative techniques for these severe wounds, including omental packing, mesh wrapping, hepatic artery ligation, hepatic resection, atriocaval shunting, gauze packing, or even hepatic transplantation.[12,17] All are associated with significant morbidity and mortality.

Typically, operation for major liver injuries requires multiple transfusions.[12,14–16] Although it is well established that transfusion of blood and blood products is a source of morbidity, it is difficult to quantitate the precise risk. The most acute complication, a hemolytic reaction, occurs approximately once for every 6000 units transfused, with a mortality rate of one per 200,000 units.[18] The risk of hepatitis B is one per 200 to 300 units, with long-term mortality from cirrhosis one per 1000 units.[18,19] The risk of hepatitis C transmission is as high as one per 15 to 20 units, but overall incidence and mortality has diminished since blood banks began widespread screening for hepatitis C.[20] The risk of human immunodeficiency virus transmission is approximately one per 100,000 to 200,000 units transfused,[18] but may be even less because screening is uniform. Overall, the long-term mortality from transfusion related disease is 0.1% to 0.15%.[19]

Several observations can be made about the management of the less severe liver injuries (grades I–II). First of all, most of these injuries already have stopped bleeding at the time of abdominal exploration. Any further hepatic hemorrhage usually follows clot extirpation and wound exploration. This observation was studied in the pediatric population, and it has been demonstrated by multiple investigators that nonoperative management of most children with blunt hepatic injury yields satisfactory results.[3,21–23] This nonoperative management scheme has been retrospectively reviewed more recently in adults by several investigators.[1–10] Overall, the results are quite favorable, with few liver-related failures. However, extrapolation of the retrospective adult reviews to a prospective protocol of management of all hepatic injuries must be made with extreme caution, because most authors have observed only the minor injuries.

Minor liver injuries will heal without operative intervention. This concept is not new; Pringle suggested it in 1908.[24] Aside from a few small series involving adult and pediatric patients, little was published regarding nonoperative management until the 1980s. Geis et al. reported 14 adults with blunt liver injuries.[25] Three patients had delayed hemorrhage, but two of these were anticoagulated. Meyer and colleagues reported 24 selected patients who were treated successfully without operation.[1] All were hemodynamically stable at presentation, had low-grade hepatic injury, and all but one had minimal hemoperitoneum. Similar results in stable patients with minor injuries and minimal hemoperitoneum were reported by Farnell et al. in 20 patients.[2] In separate studies, both Hiatt et al. and Federico et al. reported that the quantity of hemoperitoneum did not correlate with failure of nonoperative management.[4,6] Although two patients with hemoperitoneum underwent explorations in one of these series,[4] both had nontherapeutic laparotomies. More recently, use of the AAST Hepatic Injury Grade has been used to quantitate severity of injury because it can incorporate CT findings to establish a grade. Pachter and colleagues reported 25 patients with grades I to III injuries who were successfully managed nonoperatively.[8] Knudson et al. reviewed 52 patients with hepatic trauma.[7] Minor injuries (grades I–II) were present in 34, and 18 (33%) had major injuries. Minimal to no hemoperitoneum was seen in 79% of patients. There was one failure in a patient with grade IV injury and moderate hemoperitoneum who was operated 3 days after injury. Recently, Meredith and colleagues reviewed 92 victims of blunt trauma who were stable enough for abdominal CT scanning.[10] Of these, 72 with liver injury were managed nonoperatively. Minor injury (grades I–II) was seen in 54%, and 46% had grades III to V wounds. Two patients required operation—both had grade IV injuries, and one had nontherapeutic laparotomy. The authors document fewer transfusions for the nonoperative group compared with the 20 who were initially explored. Although selection for operation relative to the liver injury was not strictly defined, the decreased transfusion requirements in patients managed without operation in this retrospective study is very important.

A prospective trial involving 60 patients with blunt liver injuries recently was reported.[26] Half underwent operations, and half were managed without operation. The authors found that the group that underwent operations had significantly higher transfusions; however, 60% of the operated patients were hemodynamically unstable. Thus, comparison of these two groups is difficult because none of those managed without operation were unstable. In the current study, consecutive patients with blunt liver injury were evaluated prospectively. The decision to operate on the liver injury was based solely on the hemodynamic status of the patient. Unless there was other significant abdominal injury that required operation, appearance of the injury on CT scan or amount of hemoperitoneum were not indications for exploration. Based on these criteria, 18% of patients with blunt liver injury will require emergent celiotomies either for the liver or associated intra-abdominal injuries, and 82% are candidates for nonoperative management. Of these, 89% will not require laparotomy, and 11% will fail nonoperative therapy. Approximately half of the failures will be liver related. The fact that 89% of hemodynamically stable patients are candidates for nonoperative therapy is considerably higher than the 20% to 50% reported in the literature.[1,4,7,10,26] It seems clear that many stable patients who have been explored previously could have been managed without exploration. Table 5 summarizes the larger studies of nonoperative hepatic injuries in which enough data were presented so that comparisons can be made. The incidence of nonoperative management ranges from 6%[1,8] to 82% in the present study. Regarding hepatic injury severity, only one other series[9] had more than a 50% incidence of grades III through V injuries. Transfusion requirements and complication rates are comparable with the present series.

The advantages of nonoperative therapy include a lower incidence of abdominal septic complications and less transfused blood with no difference in mortality. When the current series was compared with a matched population of patients from our institution with liver injury who were evaluated prospectively, there were several interesting findings. Overall liver-related abdominal complications occurred in 3% of those patients managed nonoperatively compared with 11% in the operated control subjects ($p < 0.04$). In patients with the most severe liver injuries, transfusion requirements were significantly less in the nonoperative group than in the group

Table 5. SUMMARY OF REPORTS OF NONOPERATIVE MANAGEMENT OF ADULT BLUNT HEPATIC INJURIES

1st Author	Duration (Months)	Nonoperative Therapy*	% Minimal Hemoperitoneum	% Minor Liver Injury	Average Transfusions	% Liver Related Failures	% Liver Related Complications
Meyer[1]	30	24 (6)	96	NA	<1.0	0	0
Farnell[2]	89	20 (30)	60	NA	2.1	10	0
Delius[3]	60	25 (63)	NA	NA	2.8	4	0
Hiatt[4]	24	16 (24)	63	NA	1.1	13	0
Federico[6]	62	16 (29)	56	69	<1.0	0	0
Knudson[7]	96	52 (20)	79	65	3.4	2	0
Pachter[8]	180	25 (6)	NA	80	2.2	0	0
Bynoe[29]	36	26 (20)	NA	62	<1.0	8	12
Durham[9]	72	22 (35)	100	41	1.3	0	0
Meredith[10]	36	72 (62)	NA	56	1.2	3	1
Sherman[26]	42	30 (50)	NA	67	2.3	0	3
Present study	22	112 (82)	45	30	1.9	5	3

* Numbers in parentheses are the percent of patients observed of the total population with blunt liver injuries over the study period.

that underwent operation (2.2 *vs.* 5.8 units; $p < 0.01$). Most liver injuries, even the most severe, probably will stop bleeding. At operation, the liver is mobilized and the clot is disturbed, causing further hemorrhage. Because most hepatic bleeding is the result of low-pressure venous hemorrhage, one would expect hemostasis to occur after injury.

Using CT criteria to determine whether to operate can be misleading. In a study comparing 37 patients with liver injuries who had preoperative CT scans, the CT grade was compared with the operative grade.[27] The CT and operative grades did not agree in 84%, with CT overestimating or underestimating the operative grade with nearly equal frequency. In the context of the present study, in which CT was used to quantitate the grade of hepatic injury, our prior work emphasizes the importance of using markers other than CT or diagnostic peritoneal lavage to select operative candidates. Diagnostic peritoneal lavage probably would have been positive in the 62 patients with moderate or large hemoperitoneum, and 58 of these patients were successfully managed nonoperatively. Thus, it appears that the best predictor of the need for operation in patients with blunt liver injury is the loss of hemodynamic stability.

Aside from the development of hemodynamic instability, it was not possible to predict liver-related failures based on injury grade, hemoperitoneum, or presence of associated injuries. One patient had failure 11 days after injury. She probably had developed hepatic artery pseudoaneurysm, which ruptured into the peritoneal cavity. She had ligation of a bleeding vessel with omental packing at the time of her operation. Another patient who had failure, who had a grade I injury on CT scan, actually had an operative grade III injury. Before his operation, he was coagulopathic because of blood loss from mangling injuries to his extremities, severe brain injury, and significant hemothorax. The other three patients with failures became hemodynamically unstable because of continued blood loss from their liver injuries and underwent exploration.

Because hepatic injury grade or hemoperitoneum, both determined with CT, are not predictors of outcome, what is the role of CT scanning in patients with nonoperative management? Although CT grading has not correlated with operative grading of hepatic injuries,[27] studies are needed using the newer generation of scanners. Perhaps correlation would be better with the new helical scanners, or even using conventional axial images from the newer scanners, as was done in the present series. The hepatic injury grading system may need to be revised to account for these changes in technology. Regardless of these issues, CT scanning is extremely important in the nonoperative management scheme. Follow-up scans within 2 to 5 days can determine changes in the appearance of the injury. We observed that the first follow-up scan showed worsening of the injury in one patient who then had hepatorrhaphy. Computed tomography also identified the two vascular complications seen in the nonoperative group and prompted angiography with embolization. Because the intrahepatic arterial injuries are not definitely addressed with nonoperative management, a small number of patients with arterial injuries will develop hepatic artery pseudoaneurysms.[28] Computed tomography can identify these lessons before development of a large intrahepatic cavity so that they are amenable to embolization, and the patient will avoid a major hepatic resection.

As previously mentioned, overall liver-related abdominal complications were less in the patients who did not undergo operation when compared with control subjects who underwent operation. The overall incidence of biloma was not different in each group, even when stratified by severity of injury. Similar complication rates involving bile collections were reported by Bynoe et al. In their series of 26 patients treated without operation, 19% developed biloma.[29] The incidence was 20% and 17% for nonoperative patients and control subjects, respectively, with the majority of bilomas occurring in the most severe injuries. Operative therapy did not affect the incidence of biloma.

Although the patients did not have celiotomy for their liver injuries, they were treated as if they had. We did not maintain the patients at strict bed rest, and they were mobilized as soon as their general condition permitted. Relative to activities after discharge, they were encouraged to return to as normal a lifestyle as possible, and were given free activity status as soon as the liver appeared normal on CT.

It has been reported that some patients have persistent hepatic defects that can last up to 2 years.[7] We did not find persistent defects to be a problem. In fact, it was quite surprising how quickly many of the most severe injuries healed. Most were healed within 3 to 4 months, and the longest interval was 13 months. Follow-up CT was used to quantitate liver healing in the current study. An alternative to long-term CT follow-up would be abdominal ultrasonography. Currently, we are investigating this modality.

As others have cautioned, nonoperative management of blunt liver injury should not be considered an option if the surgeon or institution is not prepared to operate immediately, should the patient deteriorate. Observation of major injuries should not be considered "conservative therapy." It requires extremely close observation in an intensive care unit by nurses and physicians experienced in trauma management. Operating room staff members should be present at all times. If any of these criteria cannot be met, the patient may be better served by transfer to an appropriate trauma center for nonoperative management.

In summary, 89% of hemodynamically stable patients with liver injury from blunt abdominal trauma can be managed safely without celiotomy, and nonoperative therapy is the treatment of choice in this population. Their incidence of liver-related complications and overall transfusion requirements are less than similarly injured operated patients. Length of hospital stay is not increased with observation. Finally, nonoperative management based solely on hemodynamically stability should be undertaken only at appropriately designated trauma centers because resources for emergent operation must always be available.

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Discussion

DR. KENNETH W. SHARP (Nashville, Tennessee): Thank you, Dr. McDonald. I appreciate Dr. Fabian and Dr. Croce giving me a copy of the paper ahead of time. This is a very nice presentation of a very anxiety-provoking group of patients. This is a lot of work and a lot of stress. It's very stressful observing patients who have a grade III, IV, or V liver injury on CT-scan.

In the interest of time, I will get straight to my questions. Several points made in the manuscript that were not brought out in the presentation, I thought, were very interesting. Liver-related failures occurred in 20% of your Grade I liver injuries. I assume that is only one patient out of five, but I am fascinated that somebody with a Grade I liver injury would fail nonoperative management. Can you tell us why that patient failed, and could that be predicted?

Secondly, can you answer your question about prediction of patients who will fail? In the manuscript, you pointed out that there are four or five patients who were explored 36 to 48 hours after the injury because their CT scan showed increasing hemoperitoneum but indeed these patients were stable. They were explored and, I believe, nontherapeutic laparotomies were done.

Are these patients failures? Would you now do the same in your next group of 100 patients?

Thirdly, I agree with the recommendation to observe these patients in the intensive care unit. That seems intuitive to me, but I don't know how long you need to observe these patients in the intensive care unit. Until they are "stable?" One day, 2 days, 4 days? One patient that disturbed me a lot in your manuscript was a patient who on day 11 became hemodynamically unstable when they ruptured their liver or a pseudoaneurysm—I'm not sure which. How long do you monitor these patients in the intensive care unit, as this will become a cost factor for you in the future?

I appreciate the opportunity to review the manuscript and to make these comments.

DR. DAVID V. FELICIANO (Atlanta, Georgia): Good morning. It's a pleasure to discuss a prospective study in this area, as it fills in so many of the gaps in our knowledge. Slowly but surely we have all come to recognize that hemodynamic stability and not the CT appearance of the liver will determine which patient should be considered for observation.

I have three questions for Dr. Croce. First, if you go back and review the original CT scans of the five liver-related failures in the study group, is there any evidence of ongoing hemorrhage or any hint that these patients would fail? Was there excessive pelvic blood that, in retrospect, might have been an indication for hepatic arteriography and embolization?

Secondly, if you take the group at highest risk for failure, that is, those with an admission blood pressure under 105 mm of mercury, would it not be more cost effective to perform early hepatic arteriography rather than watchful waiting for 1 or 2 weeks in the hospital?

And, finally, the problem or the question that is asked by community surgeons around the country when they have to deal with this, is what do you do if your CT scan at 5 days after injury shows absolutely no improvement, or even worsening, but the patient remains stable?

I enjoyed this excellent presentation. I thank the authors for a copy of the manuscript, and the Southern for the privilege of the floor.

DR. J. DAVID RICHARDSON (Louisville, Kentucky): Several of my comments and questions have already been made. I think this is an excellent paper. And, I think, as Wayne Meredith and others of this Association have shown, there is no doubt that we can do nonoperative treatment and do it safely in most patients.

It seems to me that the value of nonoperative treatment is not in saving blood or money or anything else, because I'm not sure that this study really showed that, at least to my satisfaction. I think the real value is in potentially saving lives from the avoidance of meddling—as Tim referred to it, "don't poke the skunk." And I certainly remember very vividly a young woman a few years ago who was completely stable, that I operated on, and we ended up in a situation where it just took one look, and that was all it took.

And she developed torrential bleeding which eventuated in liver packing and subsequent death from sepsis. I have encountered a few other cases where I thought we did not do the patient