Reevaluation of Hepatic Angioembolization for Trauma in Stable Patients: Weighing the Risk

Jason M Samuels, MD, Heather Carmichael, MD, Alexandra Kovar, MD, Shane Urban, BSN, RN, Stephanie Vega, MBA, BSN, RN, Catherine Velopulos, MD, MHS, FACS, Robert C McIntyre Jr, MD, FACS

BACKGROUND: Angioembolization (AE) is recommended for extravasation from liver injury on CT. Data supporting AE are limited to retrospective series that have found low mortality but high morbidity. These studies did not focus on stable patients. We hypothesized that AE is associated with increased complications without improving mortality in stable patients.

STUDY DESIGN: We queried the 2016 Trauma Quality Improvement Project database for patients with grade III or higher liver injury (Organ Injury Score $\geq$ 3), blunt mechanism, with stable vitals (systolic blood pressure $\geq$ 90 mmHg and heart rate of 50 to 110 beats/min). Exclusion criteria were nonhepatic intra-abdominal or pelvic injury (Organ Injury Score $\geq$ 3), laparotomy less than 6 hours, and AE implementation more than 24 hours. Patients were matched 1:2 (AE to non-AE) on age, sex, Injury Severity Score, liver Organ Injury Score, arrival systolic blood pressure and heart rate, and transfusion in the first 4 hours using propensity score logistic modeling. Primary outcomes were in-hospital mortality, length of stay, transfusion, hepatic resection, interventional radiology drainage, and endoscopic procedure.

RESULTS: There were 1,939 patients who met criteria, with 116 (6%) undergoing hepatic AE. Median time to embolization was 3.3 hours. After successfully matching on all variables, groups did not differ with respect to mortality (5.4% vs 3.2%; $p = 0.5$, AE vs non-AE, respectively) or transfusion at 4 to 24 hours (4.4% vs 7.5%; $p = 0.4$). A larger percentage of the AE group underwent interventional radiology drainage (13.3% vs 2.2%; $p < 0.001$), with more ICU days (4 vs 3 days; $p = 0.005$) and longer length of stay (10 vs 6 days; $p < 0.001$).

CONCLUSIONS: Hepatic AE was associated with increased morbidity without improving mortality, suggesting the benefits of AE do not outweigh the risks in stable liver injury. Observing these patients is likely a more prudent approach. (J Am Coll Surg 2020;231:123−132. © 2020 by the American College of Surgeons. Published by Elsevier Inc. All rights reserved.)

Hepatic angioembolization (AE) has gained widespread acceptance for the management of traumatic liver injury. Both the Western Trauma Association and Eastern Association for the Surgery of Trauma recommend using hepatic AE for blunt liver injury.[1,2] However, limited data exist evaluating the effectiveness of hepatic AE and the complications that arise after its use, and data are limited to small observational case series and systematic reviews with no comparative studies published to date.[3-9]

Retrospective case series have found hepatic AE to be highly effective, as defined by either low re-bleeding rates or reduced need for re-interventions across a broad population of patients.[4] Additionally, hepatic AE appears to carry a low mortality risk. However, complications after hepatic AE have remained a concern, with the possibility of embolization leading to hepatic and gallbladder necrosis, persistent bile leaks and bilomas, abscesses, and iatrogenic injury to the hepatic vasculature. Mohr and colleagues[3] first raised concerns of morbidity with hepatic AE in 2003, reporting a 58% liver-related complication rate after hepatic AE, and a more recent series by Dabbs and colleagues[5] found an even higher frequency of

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From the Department of Surgery, University of Colorado Anschutz (Samuels, Carmichael, Kovar, Velopulos, McIntyre) and Trauma Services, University of Colorado Hospital (Urban, Vega), Aurora, CO.

Correspondence address: Jason M Samuels, MD, Department of Surgery, University of Colorado Anschutz, 12636 East 17th Ave, Room 5401, Aurora, CO 80045. email: Jason.Samuels@cuanschutz.edu

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Abbreviations and Acronyms

AE = angioembolization
AIS = Abbreviated Injury Scale
IR = interventional radiology
OIS = Organ Injury Score
TQIP = Trauma Quality Improvement Project

liver-related complication, with 70% experiencing liver-related morbidity.

The use of nonselective embolization might explain the high rate of complication after hepatic AE reported in earlier studies; however, despite the growth of selective and subselective embolization, recent case series continue to find a high rate of liver-related complication after AE.[9] Earlier studies primarily included unstable patients and patients requiring transfusion or an intervention. The impact of hepatic AE and the complication rate in stable liver-injured patients remains unclear.

Therefore, this study aimed to evaluate outcomes after the use of hepatic AE, as well as the frequency of complication for isolated liver injury in the stable trauma patient. We hypothesized that hepatic AE is not associated with improved in-hospital mortality in this population, but is associated with a higher complication rate, with increased frequency of endoscopic and interventional radiographic intervention.

METHODS

Study design

This is a retrospective study using the 2016 Trauma Quality Improvement Project (TQIP) database. In 2016, there were 485 centers contributing data to the TQIP database. This study was approved by the Colorado Multiple IRB (COMIRB 19-0980).

Inclusion and exclusion criteria

The TQIP database was queried to identify adult (16 years or older) patients with grade III or higher liver injury (Organ Injury Score [OIS] of the liver $\geq$ 3) and blunt mechanism.[10] Injury scoring in TQIP is coded using the American Association for the Surgery of Trauma OIS, with the highest score for each body region used to determine the Abbreviated Injury Scale (AIS) score for that region.[10] As the most recent updates to the American Association for the Surgery of Trauma OIS occurred in 2018, the 2016 TQIP data are based on the earlier scoring system from 1994, which does not incorporate vascular injury or extravasation.[11] Patients with additional intra-abdominal or pelvic injury were identified using individual OIS data collected in TQIP, and patients with intra-abdominal (nonhepatic) or pelvic OIS $\geq$ 3 were excluded. Patients were included if they presented with stable vital signs, defined as systolic blood pressure $\geq$ 90 mmHg and heart rate between 50 and 110 beats/min. Patients who were taken to the operating room for laparotomy within 6 hours and patients who underwent AE $\geq$ 24 hours after arrival were also excluded (Fig. 1).

Patients who underwent operation for liver injury before AE were identified using ICD-10 codes for liver-related procedures. Patients who underwent interventional radiology (IR) drainage and biliary endoscopic procedures were similarly identified using ICD-10 codes. A full list of the liver procedure codes and description of each ICD-10 code can be found in eTable 1.

Outcomes

The primary outcomes were in-hospital mortality, hospital length of stay, need for blood transfusion, hepatic resection, IR drain placement, and need for endoscopic procedure. TQIP does not directly track liver-related complication such as hepatic necrosis or bile leak. However, this study analyzes the occurrences of the procedures mentioned (eg hepatic resection and IR drain placement) as a surrogate for the occurrence of severe liver-related complication requiring an intervention. Secondary outcomes were discharge destination (eg home, home with home health, or facility) and TQIP-tracked complications, including surgical site infection, deep venous thrombosis and pulmonary embolism, acute respiratory distress syndrome, and unplanned ICU admission and intubation.

Statistical analysis

All statistical analyses were performed using R statistical software (version 3.3.3; R Foundation for Statistical Computing). For univariate comparisons presented in the tables, a chi-square test with continuity correction was used when comparing proportions, with the exception of comparisons where the frequency was 5 or fewer, in which case Fisher exact test was used. A Wilcoxon rank sum test was used for continuous variables. For primary outcomes, a 2-sided p value < 0.05 was considered significant. To address the risk of a type 1 error due to multiple comparisons, comparisons for secondary outcomes were only considered to be significant if the 2-sided p value was < 0.01.[12] The package "MatchIt" was used for propensity score matching. Propensity score matching was performed in a 1:2 ratio using a nearest-neighbor method with a logistic regression model used to estimate the propensity score.[13] Patients were matched according to the following criteria: age, sex, ISS, admission systolic blood pressure, admission

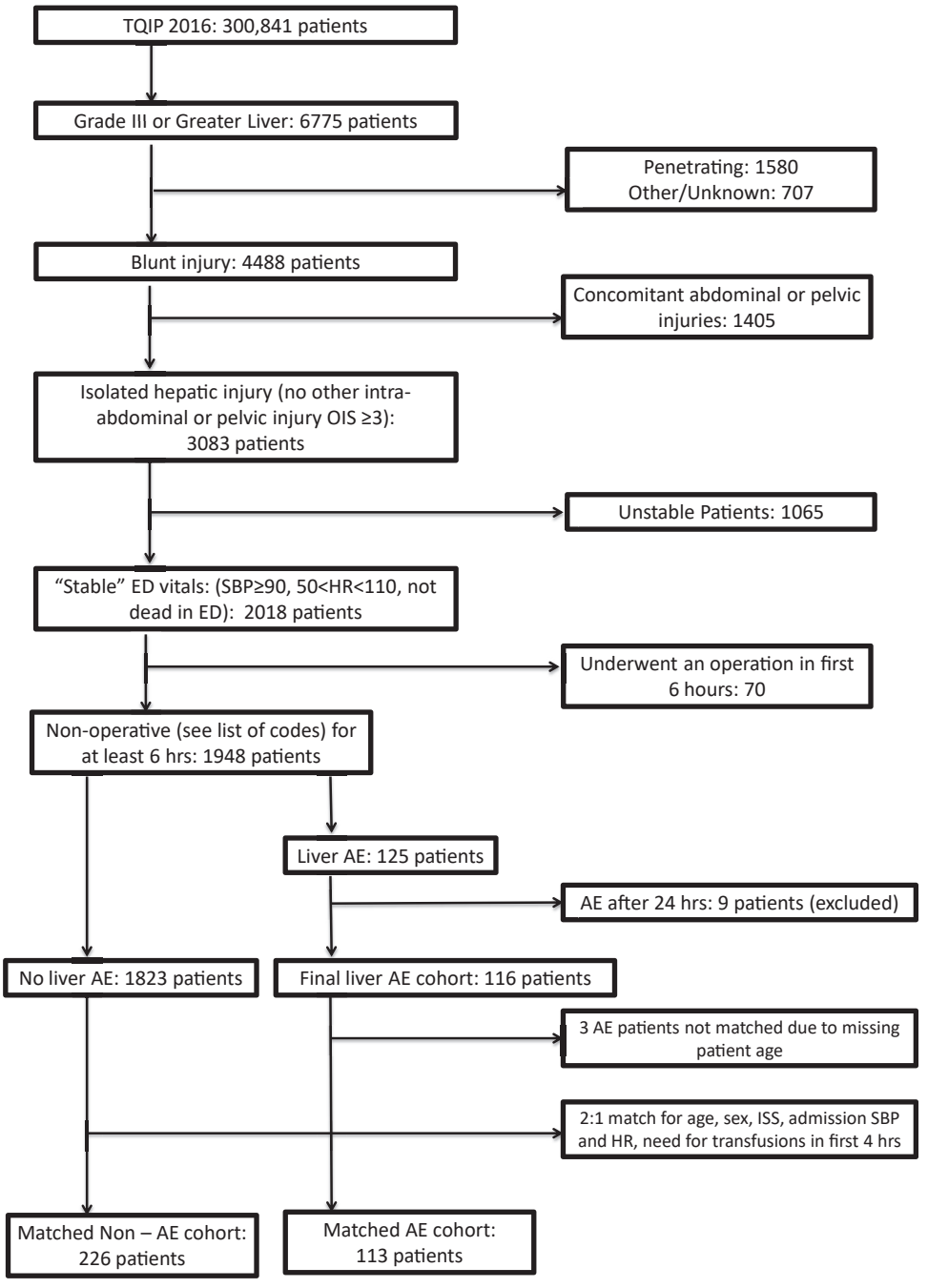

Figure 1. Flowchart of patient selection. AE, angioembolization; AIS, Abbreviated Injury Scale; ED, emergency department; HR, heart rate; OIS, Organ Injury Scale; SBP, systolic blood pressure; TQIP, Trauma Quality Improvement Project.

heart rate, and need for blood transfusion in the first 4 hours from admission. All of these were continuous variables, with the exception of sex and need for blood transfusion, which were binary. Transfusions in the first 4 hours were used as part of the matching algorithm because need for transfusion was significantly different between groups and was likely a factor in patients needing AE.

Table 1. Demographics and Selected Baseline Characteristics Before Matching with Comparison of Eligible Nonmatched Hepatic Angioembolization and Nonangioembolization Patients

Characteristic	All patients (n = 1,939)	Non-AE (n = 1,823)	AE (n = 116)	p Value*
Demographic				
Age, y, median (IQR)	32 (23–48)	32 (23–47)	36 (24–54)	0.04
Sex, m, n (%)	1,102 (56.8)	1,036 (56.8)	66 (56.9)	0.99
Hospital type, n (%)				0.48
Community	709 (36.6)	671 (36.8)	38 (32.8)	
Nonteaching	182 (9.4)	168 (9.2)	14 (12.1)	
University	1,048 (54.0)	984 (54.0)	64 (55.2)	
Insurance type, n (%)				0.003
Private/commercial	941 (48.5)	885 (48.5)	56 (48.3)	
Medicaid	357 (18.4)	345 (18.9)	12 (10.3)	
Medicare	140 (7.2)	122 (6.7)	18 (15.5)	
Self-pay	262 (13.5)	246 (13.5)	16 (13.8)	
Other/unknown	239 (12.3)	225 (12.3)	14 (12.1)	
Injury				
Liver Organ Injury score, n (%)				< 0.001
Grade III	1,225 (63.2)	1,194 (65.5)	31 (26.7)	
Grade IV	577 (29.8)	518 (28.4)	59 (50.9)	
Grade V	137 (7.1)	111 (6.1)	26 (22.4)	
Injury Severity Score, median (IQR)	22 (17–29)	22 (16–27)	25 (18–29)	0.001
Abbreviated Injury Scale score, n (%)				
Head ≥ 3	243 (12.5)	234 (12.8)	9 (7.8)	0.15
Chest ≥ 3	893 (46.1)	837 (45.9)	56 (48.3)	0.69
Lower extremity ≥ 3	256 (13.2)	245 (13.4)	11 (9.5)	0.28
Systolic blood pressure, mmHg, median (IQR)	128 (114–142)	129 (114–142)	124 (110–143)	0.20
Heart rate, beats/min, median (IQR)	88 (78–98)	88 (78–98)	89 (80–98)	0.62

*Comparing AE with non-AE patients.
AE, angioembolization; IQR, interquartile range.

RESULTS

Study patients

In 2016 in TQIP, 6,775 patients were found to have liver injury grade III or higher; 1,939 patients (28.6%) met inclusion criteria, with 116 of those (6.0%) undergoing hepatic AE (Fig. 1). Median time to embolization was 3.3 hours (range 0.2 to 17.7 hours). There was no statistically significant difference between the 2 groups in rates of concomitant head injury, chest injury, or lower extremity injury with AIS ≥ 3 (Table 1). Before matching, the AE group had higher grade of liver injury ($p < 0.001$) and had a higher Injury Severity Score (median 22 vs 25, non-AE vs AE groups, respectively; $p = 0.001$). All but 3 of the AE patients were successfully matched with non-AE patients, with no statistically significant difference between the 2 matched groups across all of the matching variables. The 3 AE patients not matched were excluded due to patient age missing in the TQIP data set.

Primary outcomes

Summary of data for the primary outcomes of interest before matching can be found in Table 2, and characteristics of the matched samples are shown in Table 3. After matching, the 2 groups did not differ significantly in mortality rate (5.3% vs 3.2%; $p = 0.48$), and the groups were not statistically significantly different in terms of need for blood transfusion between 4 and 24 hours (4.4% vs 7.5%; $p = 0.39$) (Table 4). There were no statistical differences in rates of hepatic resection or endoscopic intervention, but the AE group had a higher rate of IR drainage (13.3% vs 2.2%; $p < 0.001$) (Table 4). Compared with matched patients, the AE group had longer length of stay (median 10 vs 6 days; $p < 0.001$) and more ICU days (median 4 vs 3; $p = 0.005$).

Secondary outcomes

After matching, the AE group had a lower, albeit not statistically significant, rate of discharge home without

Table 2. Blood Product Use and Outcomes Before Matching of the Angioembolization and Nonangioembolization Groups

Outcome	All patients (n = 1,939)	Non-AE (n = 1,823)	AE (n = 116)	p Value*
Blood product, n (%)				
Any packed RBCs in 4 h	163 (8.4)	127 (7.0)	36 (31.0)	< 0.001
Any packed RBCs between 4 and 24 h	36 (1.9)	30 (1.6)	6 (5.2)	0.018
Other outcome				
Mortality, n (%)	53 (2.7)	46 (2.5)	7 (6.0)	0.05
Discharge, n (%)				0.001
Dead	53 (2.7)	46 (2.5)	7 (6.0)	
Home health	120 (6.2)	107 (5.9)	13 (11.2)	
Home	1,311 (67.6)	1,249 (68.5)	62 (53.4)	
Facility	420 (21.7)	388 (21.3)	32 (27.6)	
Unknown	35 (1.8)	33 (1.8)	2 (1.7)	
Hospital LOS, d, median (IQR)	5 (3–9)	5 (3–9)	10 (5–16)	< 0.001
ICU LOS, d, median (IQR)	3 (2, 5)	2 (1,4)	4 (2, 7)	< 0.001
Ventilator days, median (IQR)	0 (0–0)	0 (0–0)	0 (0–2)	0.016
Late laparotomy (after 6 h), n (%)	37 (1.9)	29 (1.6)	8 (6.9)	< 0.001
Endoscopic procedure, n (%)	12 (0.6)	9 (0.5)	3 (2.6)	0.03
Drain procedure, n (%)	30 (1.5)	15 (0.8)	15 (12.9)	< 0.001
Hepatic resection > 24 h after injury, n (%)	4 (0.2)	2 (0.1)	2 (1.7)	0.008

*Comparing AE with non-AE patients.
AE, angioembolization; IQR, interquartile range; LOS, length of stay.

services (55.0% vs 68.2%). However, the matched groups did not differ in the frequency of any TQIP-tracked complications, including organ space infection or acute kidney injury (Table 4).

DISCUSSION

This matched analysis comparing stable patients with blunt, isolated hepatic injury found hepatic AE was not associated with an improvement in mortality and no association was found with hepatic AE and a decrease in blood transfusions. Additionally, hepatic AE was associated with an increase in hospital resource use with increased ICU days and overall length of stay and was associated with an increase in morbidity with increased need for IR drain placement.

Several small retrospective studies have suggested that hepatic AE for liver injury is an effective intervention. The largest systematic review by Virdis and colleagues[14] found hepatic AE was highly effective, with reported success rates ranging from 80% to 97%. The largest single-center study by Xu and colleagues[15] reported just 7% of the 114 patients who underwent hepatic AE had failure compared with 17% of patients in the study who failed nonoperative management without AE. Our study was unable to directly evaluate effectiveness of AE; however, we were able to compare key measures, such as mortality, need for liver-related operation, and need for transfusion. Although hepatic AE appears to carry a low mortality, this might reflect the stability of the patient population undergoing AE, or that AE effectively limits blood loss, hemorrhagic shock, and the subsequent sequelae. Li and colleagues[8] reported zero mortality after hepatic AE in 35 liver-injured patients; however, the larger cohort of patients managed without AE (72 total patients) in this study also had zero mortality. One might anticipate hepatic AE would decrease mortality with earlier control of hemorrhage. Lee and colleagues[7] found that stable patients without tachycardia or hypotension were more likely to have successful AE with a lower mortality rate. Our study similarly focused on patients with stable vitals on arrival, and there was no difference seen in mortality between groups.

Limited data exist evaluating the impact of hepatic AE on need for blood transfusion. Duane and colleagues[16] in 2000 first suggested use of AE for hepatic injuries might lead to a lower transfusion requirement and the administration of less crystalloid. However, in our study, there was no difference between the 2 groups in the percentage of patients who required blood products from 4 to 24 hours. The systematic review by Green and colleagues[4] found patients who underwent early embolization required an average of 5.8 units of blood in the first 24 hours. For comparison, the AE cohort in our study received an average of < 1 unit of blood (mean of 0.8 units). The difference between our results and the review

Table 3. Characteristics of Angioembolization and Nonangioembolization Patients After Propensity Score Matching

Characteristic	Non-AE (n = 226)	AE (n = 113*)	p Value
Demographic			
Age, y, median (IQR)	35 (24–54)	36 (24–54)	0.64
Sex, m, n (%)	136 (60.2)	64 (56.6)	0.61
Hospital type, n (%)			0.86
Community	72 (31.9)	37 (32.7)	
Nonteaching	33 (14.6)	14 (12.4)	
University	121 (53.5)	62 (54.9)	
Insurance type (%)			0.62
Private/commercial	111 (49.1)	55 (48.7)	
Medicaid	32 (14.2)	12 (10.6)	
Medicare	24 (10.6)	18 (15.9)	
Self-pay	31 (13.7)	16 (14.2)	
Other/unknown	28 (12.4)	12 (10.6)	
Injury			
Liver Organ Injury score (%)			0.67
Grade III	62 (27.4)	31 (27.4)	
Grade IV	121 (53.5)	56 (49.6)	
Grade V	43 (19.0)	26 (23.0)	
Injury Severity Score, median (IQR)	25 (17–30)	25 (18–30)	0.85
Abbreviated Injury Scale score, n (%)			
Head $\geq$ 3	24 (10.6)	9 (8.0)	0.56
Chest $\geq$ 3	95 (42.0)	54 (47.8)	0.37
Lower extremity $\geq$ 3	32 (14.2)	11 (9.7)	0.33
Systolic blood pressure, mmHg, median (IQR)	125 (110–138)	123 (110–142)	0.96
Heart rate, beats/min, median (IQR)	89 (78–99)	89 (79–97)	0.8

Patients matched on age, sex, Injury Severity Score, severity of liver injury, initial systolic blood pressure and heart rate, and need for blood in the first 4 h of admission.
*Three AE patients were not matched due to patient age missing in the Trauma Quality Improvement Project data set.
AE, angioembolization; IQR, interquartile range.

by Green and colleagues likely reflects the stable nature of the cohorts compared in this study. In the setting of a patient not requiring blood products and with stable vitals, the patient is unlikely to be bleeding significantly and would gain little benefit from AE. Despite this, current guidelines, such as those from the Western Trauma Association, recommend hepatic AE for blush on CT scan after blunt hepatic injury, regardless of vitals or blood transfusion requirements.[1] The data presented here suggest against the implementation of hepatic AE in stable patients not requiring transfusions.

Another reason hepatic AE use should be considered cautiously is the risk for morbidity after embolization. Complications after hepatic AE have been a persistent concern since early use for high-grade hepatic injury. These complications include hepatic or gallbladder necrosis, formation of biloma or perihepatic abscesses, and persistent bile leak. Mohr and colleagues[3] in 2003 first highlighted a significant rate of hepatic-related complication after hepatic AE with 45% of patients with complications after undergoing early hepatic AE (immediately after CT scan). Dabbs and colleagues[5] in 2009 reported an even higher complication rate in a larger sample with > 60% of patients experiencing a liver-related complication after hepatic AE. The most recent systematic review by Virdis and colleagues[14] found a wide range of reported morbidity after hepatic AE of 5% to 93%. This range might reflect improvements in catheter technologies with better selectivity of subsegmental arteries in more recent series.

Using need for an IR drainage procedure as a surrogate for hepatic-related complication, data reported here suggest complications remain a persistent problem after the use of hepatic AE. In addition, the group undergoing hepatic AE in this study had greater ICU days and longer length of stay, reflecting a more complex hospital course. The lack of mortality benefit and the association with increased morbidity raises the issue of whether hepatic AE provides a true benefit over a noninterventional approach.

Table 4. Blood Product Use and Outcomes after Propensity Score Matching of the Angioembolization and Non-angioembolization Groups

Outcome	Non-AE (n = 226)	AE (n = 113)	p Value
Blood product, n (%)			
Any packed RBCs in 4 h	58 (25.7)	35 (31.0)	0.37
Any packed RBCs between 4 and 24 h	17 (7.5)	5 (4.4)	0.39
Other outcome			
In-hospital mortality, n (%)	7 (3.1)	6 (5.3)	0.48
Discharge, n (%)			0.09
Death	7 (3.1)	6 (5.3)	
Home health	14 (6.2)	13 (11.5)	
Home	150 (66.4)	61 (54.0)	
Facility	49 (21.7)	31 (27.4)	
Unknown	6 (2.6)	2 (1.8)	
Hospital LOS, d, median (IQR)	6 (4−10)	10 (5−16)	< 0.001
ICU LOS, d, median (IQR)	3 (2−5)	4 (2−7)	0.005
Ventilator days, median (IQR)	0 (0−0)	0 (0−2)	0.45
Late laparotomy (after 6 h), n (%)	8 (3.5)	8 (7.1)	0.24
Endoscopic procedure, n (%)	4 (1.8)	3 (2.7)	0.89
Drain procedure, n (%)	5 (2.2)	15 (13.3)	< 0.001
Hepatic resection > 24 h after injury, n (%)	1 (0.4)	2 (1.8)	0.54
Complication, n (%)*			
Acute kidney injury	3 (1.3)	4 (3.5)	
Acute respiratory distress syndrome	2 (0.9)	0 (0.0)	
Cardiac arrest with CPR	3 (1.3)	1 (0.9)	
Catheter-associated urinary tract infection	3 (1.3)	0 (0.0)	
Deep surgical site infection	1 (0.4)	1 (0.9)	
Deep vein thrombosis	3 (1.3)	3 (2.7)	
Extremity compartment syndrome	1 (0.4)	0 (0.0)	
Organ space surgical site infection	3 (1.3)	3 (2.7)	
Pulmonary embolism	3 (1.3)	0 (0.0)	
Severe sepsis	3 (1.3)	1 (0.9)	
Superficial surgical site infection	0 (0.0)	1 (0.9)	
Unplanned admission to the ICU	7 (3.1)	5 (4.4)	
Unplanned intubation	5 (2.2)	4 (3.5)	
Unplanned return to the operating room	0 (0.0)	1 (0.9)	
Ventilator-associated pneumonia	3 (1.3)	3 (2.7)	
Any complication	21 (9.3)	20 (17.7)	0.033

*All p values for comparison of individual complication > 0.1.
AE, angioembolization; IQR, interquartile range; LOS, length of stay.

Given these findings, AE is likely best done in a selective fashion. Determining which patients would benefit from hepatic AE becomes paramount. A similar evolution was seen in the management of splenic injury. Early studies suggested mandatory embolization of splenic injury, regardless of hemodynamics,[17] but subsequent reports suggested a more selected approach was feasible.[18,19] Such data identifying which liver-injured patients would benefit from AE do not yet exist. In the era of high-definition CT scanning, the frequency of identifying patients with contrast extravasation or high-grade liver injury is likely to increase. These data suggest imaging alone should not guide management of liver injury, given the risk of comorbidities with liver-directed intervention. Rather than empirically treating imaging findings, the decision to implement AE for hepatic trauma should be guided by the clinical picture, such as in the setting of a decompensating patient or one with ongoing transfusion requirements. A modern, prospective assessment of AE in liver-injured patients is needed, especially in those

with stable hemodynamics who could tolerate a noninterventional approach.

This study has several limitations beyond the retrospective nature and the constraints of propensity matching. First, the data within TQIP are limited in granularity and do not identify the true indication for hepatic AE. For example, it remains unknown whether those who underwent embolization did so due to identifiable signs of active hemorrhage, such as arterial extravasation on imaging or whether AE was done empirically due to a change in a patient's clinical picture, such as the development of hypotension. We attempted to control for these confounders, albeit imperfectly, by using the need for transfusion in the first 4 hours as an indicator of clinical differences not captured by grade of injury. No data-driven indications for embolization have been identified previously, and whether patients truly benefited from embolization in these scenarios remains unknown regardless of indication. Second, this study relies on accurate coding to identify patients with significant extrahepatic injury. The possibility remains that patients' conditions were driven more by an injury unrelated to their liver injury, despite our attempts to control for these factors. Additionally, TQIP includes patients with missing data, and whether these missing data occur in a manner that might bias the results is not known. Third, we do not know the type of embolization method used (eg selective vs subselective, or gelfoam vs coils), and this variable represents another potential confounder. Lastly, TQIP does not directly track liver-related complication, such as bile leak or perihepatic abscesses. This study attempted to use procedures frequently used to manage complication as a signal that these liver-related complications occurred, but we cannot say definitively that the procedures were done for these complications. To address these limitations and better answer the questions raised, we are leading a Western Trauma Association multicenter study that is currently prospectively enrolling patients across 15 centers in the US. We hope this study will better delineate the true efficacy and complication rates associated with hepatic AE.

CONCLUSIONS

The benefit of AE of hepatic injury remains unclear, particularly in the clinically stable patient. Hepatic AE in stable, isolated liver injury was associated with increased morbidity and resource use, but is not associated with decreased mortality, suggesting the benefits of AE did not outweigh the risk. Observing these patients might prove equally effective without the morbidity risk of an intervention. This is the first study to use a matched control group to compare with patients undergoing hepatic AE, providing evidence that a prospective evaluation of hepatic AE use for traumatic liver injury is both feasible and needed.

Author Contributions

Study conception and design: Samuels, Carmichael, Velopulos, McIntyre

Acquisition of data: Samuels, Carmichael, Kovar, Urban

Analysis and interpretation of data: Samuels, Carmichael, Velopulos, McIntyre

Drafting of manuscript: Samuels, Carmichael, Kovar, Urban, Vega, Velopulos, McIntyre

Critical revision: Samuels, Carmichael, Kovar, Urban, Vega, Velopulos, McIntyre

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Discussion

DR CARLOS VR BROWN (Austin, TX): Dr Samuels, Dr McIntyre, and their colleagues at the University of Colorado, Denver have re-evaluated the role of angioembolization in severe liver trauma, a practice that has become relatively standard across trauma centers in this country, despite a paucity of evidence to support its use. All trauma surgeons manage liver injury on a regular basis, and usually, the management is quite straightforward. Most liver injuries are low grade with minimal bleeding, have no evidence of contrast extravasation on CT scan, are managed nonoperatively, and do quite well. On the other end of the spectrum is the unstable patient with a liver injury, who is taken directly to the operating room for laparotomy. Both groups of patients are

straightforward and do not require complex decision making. However, the hemodynamically stable patient with a moderate-to-high grade injury and contrast extravasation can be a challenge to take care of, and indication and application of hepatic angioembolization are unclear. This study attempts to add some clarity to the use of hepatic angioembolization in the care of patients with severe liver injury.

Numerous indications for hepatic angioembolization exist, including an episode of hypotension, grade of liver injury, amount of hemoperitoneum, and contrast extravasation. In addition, there are numerous types of contrast extravasation, including pseudoaneurysm, arteriovenous malformation, and contained vs free contrast extravasation, all with potentially different management and outcome implications. Using the Trauma Quality Improvement Program (TQIP) will not allow you to determine the indications for hepatic angioembolization nor the type of contrast extravasation, so how can you account for these potential variables and differences in your analysis?

In the Methods section, your inclusion was liver injury with Abbreviated Injury Score (AIS) $\geq$ 3, but one of your exclusion criteria was also abdominal AIS $\geq$ 3. I realize you were trying to exclude other severe abdominal injuries, but what methodology did you use to make sure you were capturing liver injuries and there wasn't another abdominal organ driving the abdominal AIS? Finally, how can you be sure that complications were related to the angioembolization rather than the severity of injury, hemorrhagic shock, or another uncaptured variable?

DR ROBERT MCINTYRE (Denver, CO): The major limitation of a large database retrospective study using a database such as TQIP is the fact that you are limited to the data that are captured by that database, and you are unable to do any analysis that captures data elements that was not originally in the database. The nuances of the different indications for angioembolization are not captured in that database, and we really cannot answer the questions that you posed about the indications such as an episode of hypotension or the severity of the liver injury and the type of extravasation that was seen on the CT scan.

We tried to answer those questions in a previous study in which we collected all of the angioembolizations done within the University of Colorado Health System and at Denver Health Medical Center, but the number of patients was so small that we really could not tease out the answers to the questions that you asked. We used organ-specific injury scoring to exclude spleen and bowel and other intra-abdominal injuries so we could get as pure a population as possible to answer the question that we were specifically interested in: does angioembolization affect or improve outcome, or does it have an adverse effect on morbidity and mortality? And we will clarify that in the revision of the manuscript.

How can we be sure that the embolization was driving the complication vs just severity of injury, hemorrhagic shock, other associated things that we did not capture?

The best example for that is with the intervention using percutaneous drainage. We really do not know that any of those other factors would be driving the need for percutaneous drain intervention. This was again one of the reasons why we excluded other abdominal injuries such that if an interventional radiology drain was placed in the left upper quadrant after a splenectomy, we did not want that to result in us assuming that that was a liver-related complication. Insofar as there is an assumption that the follow-up interventions are related to the liver injury, we do not know that it is one of those other factors that could be driving that complication.

DR DANIEL MARGULIES (Los Angeles, CA): Initial angioembolization has a number of benefits. One is to stop the bleeding, but also potentially, it will reduce the number of pseudoaneurysms later. The implication from your study is that it might not be necessary in certain situations despite the blush. Do you have any information on those who did not have angioembolization early on as to whether they got further study to make sure, in terms of

eTable 1. Liver Procedure Codes and Description

Procedure code	Description
Liver-specific operative management	
0DJW0ZZ	Inspection of peritoneum, open approach
0WJG0ZZ	Inspection of peritoneal cavity, open approach
04L30CZ	Occlusion of hepatic artery with extraluminal device, open approach
04L30DZ	Occlusion of hepatic artery with intraluminal device, open approach
04L30ZZ	Occlusion of hepatic artery, open approach
04Q30ZZ	Repair hepatic artery, open approach
04V30CZ	Restriction of hepatic artery with extraluminal device, open approach
04V30DZ	Restriction of hepatic artery with intraluminal device, open approach
04V30ZZ	Restriction of hepatic artery, open approach
06L40CZ	Occlusion of hepatic vein with extraluminal device, open approach
06L40DZ	Occlusion of hepatic vein with intraluminal device, open approach
06L40ZZ	Occlusion of hepatic vein, open approach
0FB00ZZ	Excision of liver, open approach
0FB10ZZ	Excision of right lobe liver, open approach
0FB20ZZ	Excision of left lobe liver, open approach
0FJ00ZZ	Inspection of liver, open approach
0FN00ZZ	Release liver, open approach
0FN20ZZ	Release left lobe liver, open approach
0FQ00ZZ	Repair liver, open approach
0FQ10ZZ	Repair right lobe liver, open approach
0FQ20ZZ	Repair left lobe liver, open approach
0FT00ZZ	Resection of liver, open approach
0FT10ZZ	Resection of right lobe liver, open approach
0FT20ZZ	Resection of left lobe liver, open approach
1OA13LA	Control of bleeding, liver open approach using manual pressure, suturing, or packing
1OA13LAAG	Control of bleeding, liver open approach using laser coagulation
1OA13LAGX	Control of bleeding, liver open approach using device NEC (eg electrocautery)
1OA13LAW0	Control of bleeding, liver open approach using synthetic agent (eg polyvinyl alcohol, microspheres, silicone, gelatin foam, polystrene, contour particles)
1OA13LAW3	Control of bleeding, liver open approach using fibrin glue
1OA13LAX7	Control of bleeding, liver open approach using chemical cautery agent
1OA13LAXXE	Control of bleeding, liver open approach using local transpositional flap (eg omental patch)
IR embolization	
04L33DZ	Occlusion of hepatic artery with intraluminal device, percutaneous approach
04L33ZZ	Occlusion of hepatic artery, percutaneous approach
04L34DZ	Occlusion of hepatic artery with intraluminal device, percutaneous endoscopic approach
04L34ZZ	Occlusion of hepatic artery, percutaneous endoscopic approach
04H33DZ	Insertion of intraluminal device into hepatic artery, percutaneous approach
04H34DZ	Insertion of intraluminal device into hepatic artery, percutaneous endoscopic approach
04V33DZ	Restriction of hepatic artery with intraluminal device, percutaneous approach
04V33ZZ	Restriction of hepatic artery, percutaneous approach
04V34DZ	Restriction of hepatic artery with intraluminal device, percutaneous endoscopic approach
04V34ZZ	Restriction of hepatic artery, percutaneous endoscopic approach
1OA13GQGE	Control of bleeding, liver percutaneous transluminal approach using (detachable) coils

(Continued)

eTable 1. Continued

Procedure code	Description
1OA13GQW0	Control of bleeding, liver percutaneous transluminal approach using synthetic agent (eg polyvinyl alcohol, microspheres, silicone, gelatin foam, polystyrene, contour particles)
Endoscopic	
0FL54DZ	Occlusion of right hepatic duct with intraluminal device, percutaneous endoscopic approach
0FL58DZ	Occlusion of right hepatic duct with intraluminal device, via natural or artificial opening endoscopic
0FLD7ZZ	Occlusion of pancreatic duct, via natural or artificial opening
0F758DZ	Dilation of right hepatic duct with intraluminal device, via natural or artificial opening endoscopic
0F758ZZ	Dilation of right hepatic duct, via natural or artificial opening endoscopic
0F768DZ	Dilation of left hepatic duct with intraluminal device, via natural or artificial opening endoscopic
0F768ZZ	Dilation of left hepatic duct, via natural or artificial opening endoscopic
0F788DZ	Dilation of cystic duct with intraluminal device, via natural or artificial opening endoscopic
0F794DZ	Dilation of common bile duct with intraluminal device, percutaneous endoscopic approach
0F794ZZ	Dilation of common bile duct, percutaneous endoscopic approach
0F798DZ	Dilation of common bile duct with intraluminal device, via natural or artificial opening endoscopic
0F798ZZ	Dilation of common bile duct, via natural or artificial opening endoscopic
0F794DZ	Dilation of common bile duct with intraluminal device, percutaneous endoscopic approach
0F794ZZ	Dilation of common bile duct, percutaneous endoscopic approach
0F798DZ	Dilation of common bile duct with intraluminal device, via natural or artificial opening endoscopic
0F7C4ZZ	Dilation of ampulla of Vater, percutaneous endoscopic approach
0F7C8DZ	Dilation of ampulla of Vater with intraluminal device, via natural or artificial opening endoscopic
0F7C8ZZ	Dilation of ampulla of Vater, via natural or artificial opening endoscopic
0FL54DZ	Occlusion of right hepatic duct with intraluminal device, percutaneous endoscopic approach
0FL58DZ	Occlusion of right hepatic duct with intraluminal device, via natural or artificial opening endoscopic
0FL94CZ	Occlusion of common bile duct with extraluminal device, percutaneous endoscopic approach
0FL94DZ	Occlusion of common bile duct with intraluminal device, percutaneous endoscopic approach
1OE52BATS	Drainage, bile ducts using endoscopic (retrograde) per orifice approach (eg ERC or ERCP) leaving catheter (tube) in situ
IR procedure for liver drainage	
0F9030Z	Drainage of liver with drainage device, percutaneous approach
0F903ZZ	Drainage of liver, percutaneous approach
0F9040Z	Drainage of liver with drainage device, percutaneous endoscopic approach
0F9130Z	Drainage of right lobe liver with drainage device, percutaneous approach
0F913ZZ	Drainage of right lobe liver, percutaneous approach
0F9230Z	Drainage of left lobe liver with drainage device, percutaneous approach
0F923ZZ	Drainage of left lobe liver, percutaneous approach
0F9430Z	Drainage of gallbladder with drainage device, percutaneous approach

(Continued)

eTable 1. Continued

Procedure code	Description
0F943ZZ	Drainage of gallbladder, percutaneous approach
0F9530Z	Drainage of right hepatic duct with drainage device, percutaneous approach
0F953ZZ	Drainage of right hepatic duct, percutaneous approach
0F9630Z	Drainage of left hepatic duct with drainage device, percutaneous approach
0F9830Z	Drainage of cystic duct with drainage device, percutaneous approach
0W9G40Z	Drainage of peritoneal cavity with drainage device, percutaneous endoscopic approach
0F993ZZ	Drainage of common bile duct, percutaneous approach
0W9G3ZZ	Drainage of peritoneal cavity, percutaneous approach
0W9G30Z	Drainage of peritoneal cavity with drainage device, percutaneous approach
1OT52HATS	Drainage, abdominal cavity using percutaneous (needle) approach and leaving drainage tube in situ

IR, interventional radiology; NEC, not elsewhere classified.