Adjunctive use of hepatic angioembolization following hemorrhage control laparotomy

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BACKGROUND: Severe liver injuries pose a challenge to trauma surgeons. While the use of hepatic angioembolization (HAE) has been evaluated as a component of the nonoperative management of liver injury, little is known about the efficacy of postoperative HAE in patients who require hemorrhage control laparotomy (HCL) for liver injury. The purpose of this study is to evaluate the impact of HAE following HCL on patient survival.

METHODS: This is a retrospective cohort study using the American College of Surgeons Trauma Quality Improvement Program database from January 2013 to December 2014. In propensity score matched (2:1) patients who underwent HCL-only or HCL + HAE, the impact of adjunctive use of HAE on patient survival was examined with the Cox proportional hazards regression analysis adjusting for transfusion requirement within 4 hours. We also performed a subgroup analysis in patients without severe traumatic brain injury (Abbreviated Injury Scale head ≤3).

RESULTS: A total of 1,675 patients met our inclusion criteria. Of those, 75 (4.5%) patients underwent HAE after HCL (median hours to HAE, 5 hours after admission). In 225 propensity score-matched patients, the use of HAE following HCL was significantly associated with improved 24-hour mortality, but not in-hospital mortality. In the subgroup of patients without severe traumatic brain injury (n = 189), we observed significant survival benefits (24-hour and in-hospital mortality) associated with the adjunctive use of HAE.

CONCLUSION: The results of our study suggest that the adjunctive use of HAE might improve survival of patients who require HCL for liver injury. Further prospective study to determine the indication for postoperative HAE is still warranted. (*J Trauma Acute Care Surg.* 2020;88: 636–643. Copyright © 2020 Wolters Kluwer Health, Inc. All rights reserved.)

LEVEL OF EVIDENCE: Therapeutic study, level III.

KEY WORDS: Liver injury; angioembolization; adjunctive use; hemorrhage control surgery.

Patients with severe liver injury continue to suffer high mortality with previous reports quoting up to 40%.[1–3] These patients often present with hemodynamic instability and require an emergent operative intervention for hemorrhage control. As the concept of damage control has been rapidly adopted for the management of severely injured patients, expedited hemorrhage control procedures, including perihepatic packing, are more commonly performed in the initial operation.[4,5] However, a previous study reported that 50% of patients who underwent damage control laparotomy had radiographic evidence of ongoing hepatic bleeding postoperatively.[6]

Over the last two decades, hepatic angioembolization (HAE) has been established as an important adjunctive therapy in the selective nonoperative management of liver injury.[3,7,8] Hemodynamically stable patients with liver injury have benefited from a nearly 100% success rate of nonoperative management and improved outcomes.[7,8] In contrast, while modern infrastructure now supports the use of endovascular procedures in the operating room (OR) (i.e., hybrid OR), there has been little investigation into the efficacy of HAE after hemorrhage control laparotomy (HCL) (Fig. 1). The purpose of this study was to examine the impact of adjunctive HAE following HCL on patient survival. We hypothesized that the adjunctive use of HAE would be significantly associated with improved survival in patients with liver injury.

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METHODS

Study Design and Patient Selection

This is a retrospective observational study using the American College of Surgeons Trauma Quality Improvement Program (ACS-TQIP) coded data files from January 2013 to December 2014. This study was approved by the Institutional Review Board of the University of Southern California. The ACS-TQIP data are a subset of the National Trauma Databank (NTDB) consisting of trauma related data collected from over 800 registered trauma centers throughout the United States. Of note, additional data concerning surgery for hemorrhagic control, transfused blood products within 4 hours and 24 hours after admission, and the timing and target organs of angioembolization are available for analysis in the TQIP. We included patients with blunt and penetrating liver injury, who were taken straight from the emergency department (ED) to the OR for HCL. In the TQIP, HCL is defined as laparotomy in a patient who required at least one unit of transfusion of packed red blood cell (PRBC) within 4 hours after admission. Exclusion criteria included: (1) patients who underwent other types of hemorrhage control surgery (e.g., thoracotomy), (2) patients who underwent HAE prior to HCL, (3) patients who did not survive more than 4 hours after admission, and (4) patients who underwent HAE after 24 hours since admission. Variables collected for the analysis were patient demographics, trauma center level, vital signs upon arrival in the ED, mechanism of injury, Abbreviated Injury Scale (AIS) for each body region, Injury Severity Score (ISS), as well as surgical procedures performed for liver injury (International Classification of Diseases-9 code: 50.22, 50.3, 50,61). The primary outcome was in-hospital mortality. Secondary outcomes included 24-hour mortality, major complications (acute kidney injury, acute respiratory distress syndrome, pneumonia, venous thromboembolism, and sepsis), hospital length of stay (LOS), intensive care unit (ICU) stay, and ventilator days.

Statistical Analysis

The final study population was comprised of patients who underwent HCL alone (HCL-only group) and those with HCL followed by HAE within 24 hours after admission (HCL + HAE

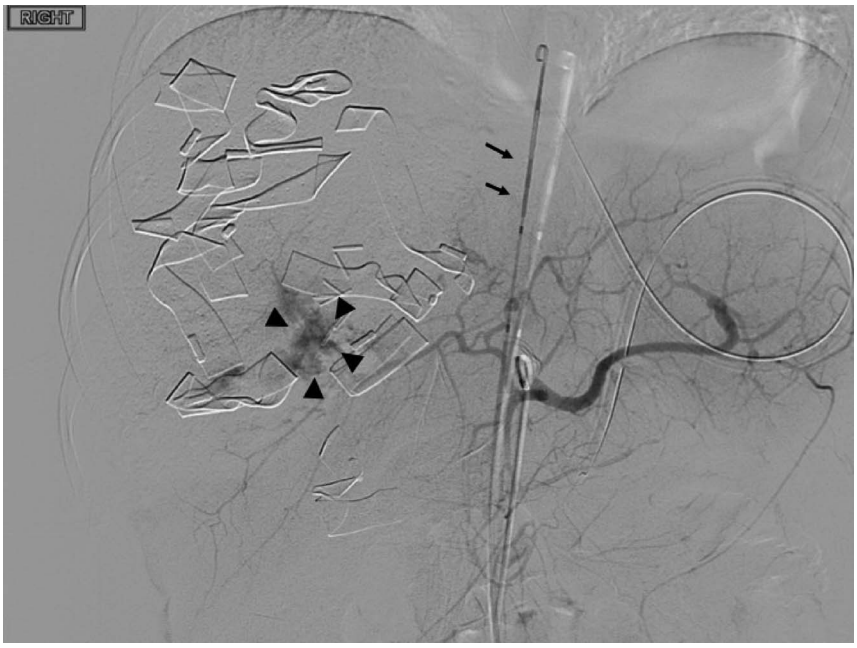

Figure 1. HAE following HCL. A case with Grade V liver injury which required HCL with non-anatomical liver resection and perihepatic packing. HAE was performed immediately after HCL in the hybrid OR. Active contrast extravasation was identified (arrowheads), then gel-form embolization was performed in the right hepatic artery. Of note, a REBOA catheter had been placed in Zone I (arrows). REBOA, resuscitative endovascular balloon occlusion of the aorta.

group). To reduce treatment assignment bias, the propensity score analysis was used to match patients in the two study groups. A propensity score for each individual patient was estimated using a logistic regression model for the outcome of adjunct use of HAE, adjusting for potential confounding factors (age, sex, admission vital signs, mechanism of injury, liver injury severity and AIS >2 in head, thorax and extremity). Subsequently, 2:1 optimal nearest neighbor matching using the propensity score between the two study groups was performed without replacement. All observed covariates were examined before and after matching between the HCL-only and HCL + HAE group. Categorical variables were expressed in percentages while continuous variables were expressed in medians with interquartile range (IQR). Univariate analysis was performed to compare between the two groups using Pearson's χ^2 test or Fisher's exact test for categorical variables and Mann-Whitney *U* test for continuous variables.[9] The survival curve of study patients was estimated using the Kaplan-Meier method and Log-rank test was performed to compare the survival times between the two groups. Subsequently, in the propensity-matched sample, we performed the Cox proportional hazards regression analysis was performed to evaluate the impact of adjunctive HAE on 24-hour and in-hospital mortality.[10] In addition to the use of adjunctive HAE, trauma center level (Level I vs. Level II) and transfusion (PRBC and plasma) requirements within 4 hours after admission were adjusted for as covariates in the model. The proportional hazard assumption was checked based on the Schoenfeld residuals.

In addition, we performed a subgroup analysis in patients without severe traumatic brain injury (TBI) to further evaluate the utility of HAE to decrease the number of hemorrhagic deaths. In the propensity score matched sample of patients with AIS head of 3 or less, the Cox proportional hazards analysis for 24 hours and in-hospital mortality was performed with trauma center level and transfusion requirements as covariates. All statistical analyses were performed using SPSS for Mac OS version 23.0 (IBM, Armonk, NY) and R (The R Foundation for Statistical Computing, ver. 3.30). Variables with p value less than 0.05 were considered significant.

RESULTS

A total of 416,104 patients were identified in the TQIP during the 2-year study period. Of those, 1,675 patients met our inclusion criteria (Fig. 2). While 75 patients underwent HCL followed by HAE, 1,600 patients only underwent HCL for liver injury. Following 2:1 propensity score matching, 150 and 75 patients from 97 unique centers were generated in the HCL-only and HCL + HAE groups, respectively. Only a small number of the patients (6.2%) underwent major liver resection (partial hepatectomy or lobectomy) during the initial operation. The median time from admission to HAE was 5 hours (IQR, 3–7) in the HCL + HAE group. Table 1 shows the comparison of patient characteristics and injury profiles between the HCL-only and HCL + HAE group before and after propensity score matching. Before matching, patients in the HCL + HAE group were more likely to sustain blunt trauma with higher ISS compared to the HCL-only group. The two study groups were well matched for basic demographics, mechanism of injury, admission vital signs, and injury severity.

Patient outcomes were compared between the propensity score matched groups (150 HCL-only vs. 75 HCL + HAE) (Table 2). Figure 3 showed survival curves for the two study groups. There were no significant differences in 24-hour and

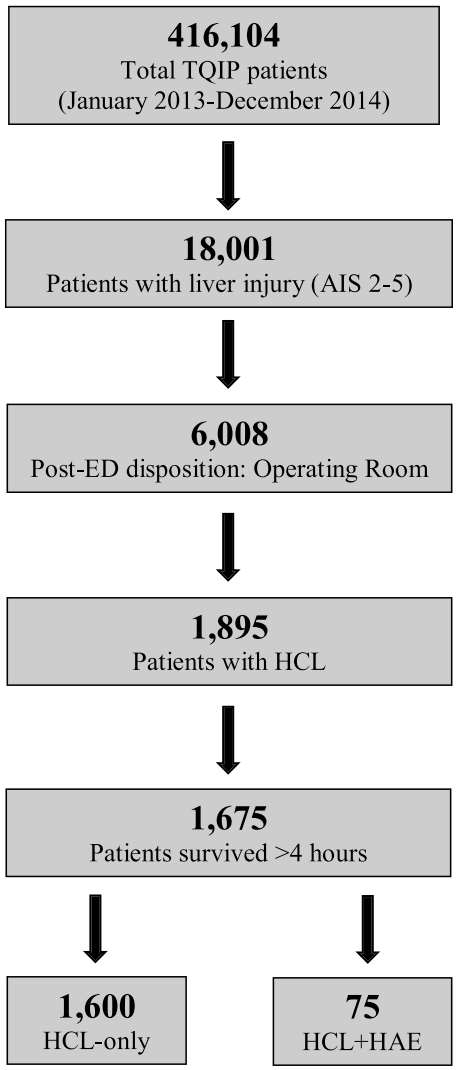

Figure 2. Study patient flow diagram.

in-hospital mortality in the univariate analysis. The median number of days from admission to death were 1 (IQR, 1–5) in the HCL-only group versus 5 (IQR, 1–9) in the HCL + HAE group ($p = 0.016$). No significant difference was found in the incidence of acute kidney injury and other major complications. In the Cox proportional hazards regression, the adjunctive use of HAE was significantly associated with improved 24-hour survival (hazard ratio [HR], 0.150; 95% confidence interval [CI], 0.041–0.540; $p = 0.004$), but not with in-hospital survival (HR, 0.571; 95% CI, 0.294–1.108; $p = 0.097$) (Table 3).

A total of 1,358 patients were identified in the subgroup of patients without severe TBI. After 2:1 matching, 126 and 63 patients from 94 centers were included in the HCL-only and HCL + HAE group, respectively (Table 4). There were no significant differences in patient characteristics, admission vital signs, and injury severity between the two groups. We observed significantly lower 24-hour mortality in the HCL + HAE group compared with the HCL-only group (6.3% vs. 17.6%, $p = 0.035$), whereas there was no significant difference in the in-hospital mortality (29.4% vs. 20.6%, $p = 0.200$) (Table 5). In the Cox regression, the use of HAE was significantly associated with improved 24-hour (HR, 0.236; 95% CI, 0.083–0.669; $p = 0.007$) and in-hospital survival (HR, 0.595; 95% CI, 0.125–0.875; $p = 0.041$) (Table 3).

DISCUSSION

In the current study using a nationwide database, the adjunct use of HAE following HCL was significantly associated with improved patient survival in propensity score matched cohorts. By using the Cox proportional hazards regression, while the use of HAE was only associated with decreased 24-hour mortality in the total matched cohorts, we observed significantly improved both 24-hour and in-hospital mortality in the subgroup of patients without severe TBI. In contrast, the use of HAE was not associated with the increased incidence of any known complications including acute kidney injury or sepsis. These results may support the adjunctive use of HAE for hemorrhage control in a selected group of patients who require HCL for liver injury.

The concept of hepatic "dearterialization" in obtaining liver hemostasis was introduced in the 1950s and subsequently applied to trauma as an adjunct in the management of massive hemorrhage from the liver injury.[11,12] Instead of surgically ligating the hepatic artery, HAE, along with developing endovascular techniques, have been used in patients undergoing damage control (DC) laparotomy for more than a decade.[3,6,13,14] Johnson et al. reported their series of seven patients (four penetrating and three blunt trauma) who underwent hepatic angiography immediately after DC laparotomy for liver injuries.[13] Of those, five (71.4%) patients had successful therapeutic HAE. In this small single-center study, there was no significant difference in mortality between DC/only (4 deaths/11) and DC/angio group (1 death/8). Asensio et al.[14] reviewed 103 operative cases for both blunt and penetrating grade IV and V liver injury and reported that 23 patients underwent HAE in 51 patients who survived to the surgical ICU postoperatively. In their analysis, postoperative HAE was significantly associated with lower in-hospital mortality (odds ratio, 0.20; 95% CI, 0.05–0.72; $p = 0.0177$). Duane et al.[3] also reported data from an institution where the liberal use of hepatic angiography was implemented in the management of high-grade blunt liver injuries. In their series, nine patients underwent HAE after operative management. No significant difference in mortality but higher complication rate and longer ICU and hospital LOS were noted compared to the patients without postoperative HAE. While they concluded that postoperative HAE may be more useful in penetrating liver injury, approximately 70% of our study patients sustained blunt liver injury. We, therefore, believe that HAE can be a valuable option regardless of injury mechanism.

The indications for postoperative HAE are yet to be determined. Further, it remains unknown whether the routine use of HAE following HCL would improve the outcomes of patients with severe liver injury. Misselbeck et al.[6] advocated the aggressive use of HAE even after successful perihepatic packing in the OR. They reported data that routine hepatic angiography after an emergent laparotomy with expedited hemorrhage control showed continued intrahepatic hemorrhage in 52% of patients. Other than the surgeon's intraoperative clinical judgment, postoperative computed tomography (CT) (<24 hours) can be used

TABLE 1. Patient Characteristics Before and After Propensity Score Matching (Total Patients)

	All patients before PSM			Matched patients after PSM		
Variables	**HCL-only (n = 1600)**	**HCL + HAE (n = 75)**	***p***	**HCL-only (n = 150)**	**HCL + HAE (n = 75)**	***p***
Demographics						
Male sex (%)	1,168 (73.0)	53 (70.7)	0.657	95 (63.3)	53 (70.7)	0.274
Median age (IQR)	33 (24–48)	29 (23–42)	<0.001	28 (22–40)	29 (23–42)	0.328
Age ≥65 (%)	125 (7.8)	2 (2.7)	0.100	7 (4.7)	2 (2.7)	0.721
Trauma center level						
Level I (%)	1,279 (82.6)	60 (81.1)	0.742	11 (7.4)	14 (18.9)	0.010
Admission vital signs						
Median SBP, mmHg (IQR)	108.5 (87–130)	103 (80–131)	0.181	101 (83–125)	103 (80–131)	0.974
Median HR, bpm (IQR)	108 (88–126)	116 (95–136)	0.010	112 (93–132)	116 (95–136)	0.394
GCS (IQR)	14 (3–15)	13 (3–15)	0.178	13 (3–15)	13 (3–15)	0.927
SBP ≤90 mmHg (%)	483 (30.2)	30 (40.0)	0.072	57 (38.0)	30 (40.0)	0.772
HR ≥120 bpm (%)	540 (33.8)	32 (42.7)	0.111	61 (40.7)	32 (42.7)	0.774
GCS <9 (%)	522 (32.6)	32 (42.7)	0.071	61 (40.7)	32 (42.7)	0.774
Injury description						
Blunt mechanism (%)	885 (55.3)	55 (73.3)	0.002	111 (74.0)	55 (73.3)	0.915
Median ISS (IQR)	29 (19–41)	34 (29–43)	<0.001	37 (29–50)	34 (29–43)	0.148
ISS >15 (%)	1,387 (86.7)	73 (97.3)	0.007	147 (98.0)	73 (97.3)	1.000
AIS Head >2 (%)	396 (24.8)	19 (25.3)	0.909	40 (26.7)	19 (25.3)	0.830
AIS Thorax >2 (%)	1,178 (73.6)	55 (73.3)	0.959	115 (76.7)	55 (73.3)	0.583
AIS Extremity >2 (%)	570 (35.6)	31 (41.3)	0.314	76 (50.7)	31 (41.3)	0.186
AIS Abdomen >2 (%)	1,374 (85.9)	74 (98.7)	0.002	148 (98.7)	74 (98.7)	1.000
Isolated liver injury (%)	615 (38.4)	46 (61.3)	<0.001	89 (59.3)	46 (61.3)	0.773

PSM, propensity score matching; SBP, systolic blood pressure; HR, heart rate; GCS, Glasgow Coma Scale,

for the assessment of continued hemorrhage from the liver. A multi-center retrospective study evaluated the utility of postoperative CT as a triage tool in 528 liver injury patients who underwent an emergent laparotomy.[15] Of 455 patients who survived the initial laparotomy, 123 patients underwent postoperative CT, and 10 hemodynamically stable patients were found to have hepatic bleeding on CT (8.1%). Positive findings on postoperative CT had 83.3% sensitivity and 75.0% specificity for positive hepatic angiography. Of note, 19 patients underwent HAE without postoperative CT (median time to HAE, 2.6 hours) based on intraoperative findings and 57.9% of them had active hepatic extravasation or pseudoaneurysm. Therefore, we should still consider HAE in cases with a high clinical suspicion of ongoing bleeding based on intraoperative findings or hemodynamic status.

Significant morbidities following HAE have been reported in previous literature.[8,16,17] The incidence of major liver necrosis following HAE was reported as high as 42.2% in high-grade (III-V) liver injuries.[17] Patients with major liver necrosis often develop infectious complications and bile leaks that require multiple surgical, endoscopic, or percutaneous interventions. In a previous study by MacKenzie et al., a multidisciplinary approach consisting of perihepatic packing followed by HAE was associated with a survival benefit but increased complication rates and hospital LOS.[18] Similarly, despite a significant survival benefit, major liver-related complications might have contributed to similar ICU and hospital LOS between the two study groups in the current study. While our data support the adjunctive use of HAE for hemorrhagic control in liver injury, one of the limitations of our study is that certain liver-

TABLE 2. Comparisons of Transfusion Requirement and Study Outcomes (Total Patients)

	Total	**HCL-only**	**HCL + HAE**	
	(N = 225)	**(n = 150)**	**(n = 75)**	***p***
Transfused products (units)*				
Within 4 h, median (IQR)				
PRBC	7 (4–14)	6 (4–11)	12 (6–23)	<0.001
Plasma	5 (2–12)	4 (2–8)	9.5 (4–16)	<0.001
Platelets	1 (0–3)	1 (0–2)	2(1–4)	0.003
Within 24 h, median (IQR)				
PRBC	10 (5–19)	8 (4–14)	16.5 (9–31)	<0.001
Plasma	7 (4–16)	6 (3–13)	12 (5–24)	<0.001
Platelets	2 (1–5)	1 (0.5–3)	4 (1–7)	<0.001
Outcomes				
24-h Mortality (%)	26 (11.6)	21(14.0)	5 (6.7)	0.105
In-hospital mortality (%)	56 (24.9)	36 (24.0)	20 (26.7)	0.663
Ventilator days, median (IQR)	6 (3–15)	4.5 (2–14)	10.5 (4–17)	0.002
ICU days, median (IQR)	9 (4–19)	8 (3–18)	14 (6–21)	0.010
Hospital LOS, median (IQR)	19 (8–30)	18 (7–30)	21 (9–30)	0.558
Major complications**				
AKI (%)	19 (9.8)	10 (7.9)	9 (13.6)	0.202
ARDS (%)	23 (11.9)	14 (11.0)	9 (13.6)	0.595
Pneumonia (%)	50 (25.9)	32 (25.2)	18 (27.3)	0.755
DVT (%)	19 (9.8)	12 (9.4)	7 (10.6)	0.798
Sepsis (%)	12(6.2)	6 (4.7)	6 (9.1)	0.345

* Only patients who survived >24 h (n = 199).
** Only patients with hospital LOS >2 days (n = 193).
AKI, acute kidney injury; ARDS, acute respiratory distress syndrome; DVT, deep vein thrombosis.

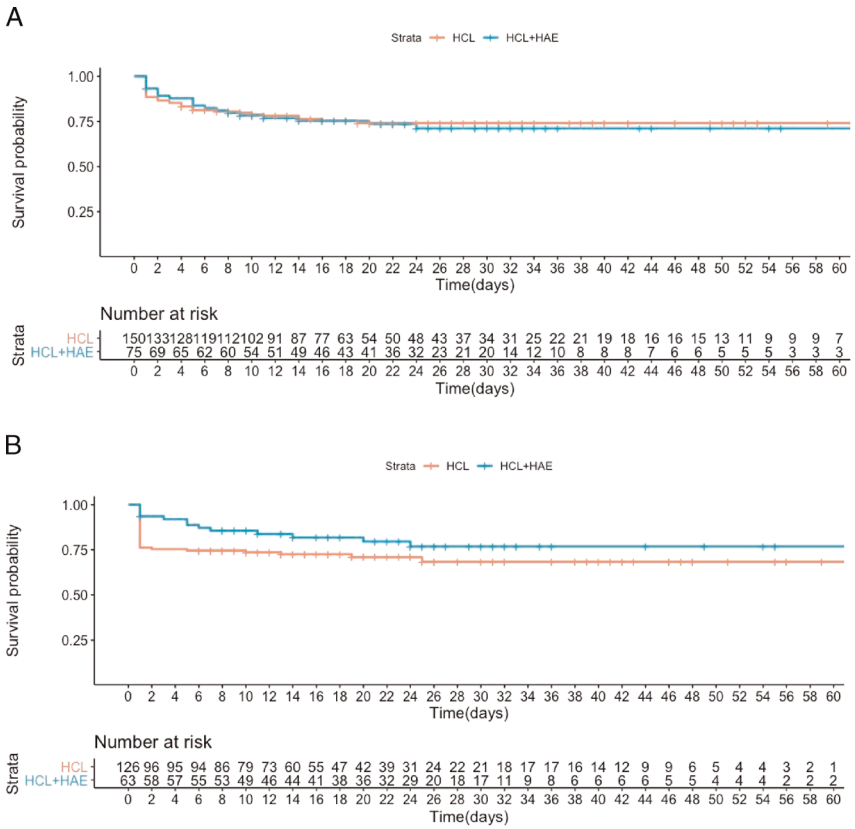

Figure 3. The Kaplan-Meier estimates of survival for (a) total patients and (b) patients without severe TBI.

related complications such as liver/gallbladder necrosis or bile leak are not collected in the TQIP. Additionally, we were unable to report how frequently patients underwent surgical, endoscopic or percutaneous interventions for those complications.

We performed the subgroup analysis in patients without severe TBI to further investigate the utility of HAE for hemorrhage control. In 75 patients who underwent HAE, the percentage of 24-hour death was only 25% (5/20). A recent study using the National Trauma Data Bank showed that the percentage of deaths over the first 24 hours was 73% in patients with severe abdominal trauma (AIS >3), whereas the percentage of 24-hour death was only 34% in severe TBI.[19] Furthermore, the historical third peak of late death (1–3 weeks) disappeared in their study cohorts between 2008 and 2014. Although we were unable to determine the cause of death in each mortality case, our results showing improved 24-hour and in-hospital survival in the subgroup analysis of patients without severe TBI may support the use of HAE to decrease the number of patients dying from acute hemorrhage.

There are several other important limitations to the current study. First, due to its retrospective nature and the limitations of the database, we were unable to determine whether the patients in the HCL + HAE group had angiographic findings suggestive of active bleeding. Although it would be uncommon, nonselective embolization of the hepatic artery might have been performed prophylactically based on the intraoperative findings. Furthermore, the indications for HAE were not standardized across the participating centers in the TQIP. Nonetheless, we

TABLE 3. Cox regression model on patient outcomes in total patients and patients without severe TBI

Outcomes	HR	95% CI	*p*
Total patients (N = 225)			
24-h Mortality			
HAE	0.150	0.041–0.540	0.004
PRBC transfusion units <4 h	1.071	0.997–1.150	0.061
FFP transfusion units <4 h	1.002	0.932–1.077	0.955
Level I trauma center	1.225	0.639–1.750	0.809
In-hospital mortality			
HAE	0.571	0.294–1.108	0.097
PRBC transfusion units <4 h	1.056	1.008–1.108	0.023
FFP transfusion units <4 h	0.996	0.949–1.046	0.873
Level I trauma center	0.931	0.341–1.563	0.948
Patients without severe TBI (n = 189)			
24-h Mortality			
HAE	0.236	0.083–0.669	0.007
PRBC transfusion units <4 h	1.001	0.994–1.008	0.759
FFP transfusion units <4 h	0.997	0.983–1.012	0.719
Level I trauma center	1.109	0.824–1.492	0.496
In-hospital mortality			
HAE	0.595	0.125–0.875	0.041
PRBC transfusion units <4 h	1.000	0.996–1.010	0.739
FFP transfusion units <4 h	0.998	0.987–1.010	0.680
Level I trauma center	1.120	0.873–1.438	0.375

FFP, fresh frozen plasma.

TABLE 4. Patient characteristics before and after propensity score matching (patients with AIS head ≤3)

	All patients before PSM			Matched patients after PSM		
Variables	HCL-only (n = 1295)	HCL + HAE (n = 63)	*p* value	HCL-only (n = 126)	HCL + HAE (n = 63)	*p* value
		Demographics				
Male sex (%)	968 (74.7)	47 (74.6)	0.979	84 (66.7)	47 (74.6)	0.265
Median age (IQR)	33 (24–48)	30 23–42)	0.19	27.5 (21–41)	30 (23–42)	0.204
Age ≥65 y (%)	101 (7.8)	1 (1.6)	0.082	9 (7.1)	1 (1.6)	0.169
Trauma center level						
Level I (%)	222 (17.6)	13 (20.6)	0.545	25 (18.5)	13 (20.6)	0.732
Admission vital signs						
Median SBP, mm Hg (IQR)	110 (90–130)	103 (72–131)	0.088	104 (86–130)	103 (72–131)	0.516
Median HR, bpm (IQR)	105 (86–123)	114 (94–130)	0.026	113.5 (99–131)	114 (94–130)	0.817
GCS (IQR)	15 (11–15)	14 (4–15)	0.084	14 (7–15)	14 (4–15)	0.676
SBP ≤90 mm Hg (%)	358 (27.6)	25 (39.7)	0.038	44 (34.9)	25 (39.7)	0.522
HR ≥120 bpm (%)	394 (30.4)	24 (38.1)	0.198	53 (42.1)	24 (38.1)	0.601
GCS <9 (%)	280 (21.6)	21 (33.3)	0.029	35 (27.8)	21 (33.3)	0.430
Injury description						
Blunt mechanism (%)	593 (45.8)	43 (68.3)	<0.001	87 (69.0)	43 (68.3)	0.912
ISS (IQR)	26 (17–34)	34 (26–41)	<0.001	34 (26–41)	34 (26–41)	0.148
ISS >15 (%)	1083 (83.6)	61 (96.8)	0.005	123 (97.6)	61 (96.8)	1.000
AIS head 1–3 (%)	91 (7.0)	7 (11.1)	0.212	15 (11.9)	7 (11.1)	0.873
AIS thorax >2 (%)	909 (70.2)	45 (71.4)	0.834	92 (73.0)	45 (71.4)	0.818
AIS extremity >2 (%)	401 (31.0)	24 (38.1)	0.233	53 (42.1)	24 (38.1)	0.601
AIS abdomen >2 (%)	1124 (86.8)	62 (98.4)	0.007	121 (96.0)	62 (98.4)	0.665
Isolated liver injury (%)	528 (40.8)	39 (61.9)	<0.001	85 (67.5)	39 (61.9)	0.516

believe that the specifics regarding HAE in the TQIP database (e.g., hours to HAE, angiography vs. angiography with embolization, specific target organ for embolization) make it an appropriate database and a strength of our study.[20] Second, although our study cohorts were admitted to multiple trauma centers (97 centers in total matched cohorts), detailed institutional-level data were not available in the TQIP for inclusion and control in the propensity score matching. The availability of hybrid ORs or in-house interventional radiologists could potentially impact the decision whether to proceed with HAE following HCL. Although it remains controversial, we adjusted for trauma center level in the Cox regression as a potential confounding factor associated with patient outcomes.[21] While no standard protocol was used for resuscitation, our results suggest that blood products were given in an appropriate ratio (>1:1:2) in our study patients requiring massive transfusion. Finally, despite propensity score matching and subsequent adjustments for transfusion requirements using the Cox regression analysis to minimize the effect of survival bias, results in our study should be interpreted with caution. Certainly, we were unable to determine whether higher transfusion requirements in the HCL + HAE group represent the severity of injuries or an aggressive resuscitation strategy in the current study.

CONCLUSIONS

Following HCL for liver injury, the majority of HAE were performed in the immediate postoperative period, between 3 hours and 7 hours after admission. In the propensity score

TABLE 5. Comparisons of transfusion requirement and study outcomes (patients with AIS head ≤3)

	Total (N = 189)	HCL-only (n = 126)	HCL + HAE (n = 63)	*p*
Transfused products (units)*				
within 4 h, median (IQR)				
PRBC	7 (4–13)	6 (4–12)	10 (4–20)	0.006
Plasma	5 (2–10)	4 (2–8)	8 (3–14)	0.003
Platelets	1 (0–3)	1 (0–2)	2 (0–4)	0.032
Within 24 h, median (IQR)				
PRBC	10 (6–18)	8 (4–15)	15 (8–26)	<0.001
Plasma	7 (4–14)	6 (2–12)	11 (4–22)	0.007
Platelets	2 (0–4)	1 (0–4)	3 (1–7)	<0.001
Outcomes				
24-h mortality (%)	26 (13.8)	22 (17.6)	4 (6.3)	0.035
In-hospital mortality (%)	50 (26.5)	37 (29.4)	13 (20.6)	0.200
Ventilator days, median (IQR)	7 (3–15)	5 (2–15)	11 (5–18)	0.008
ICU days, median (IQR)	11 (4–19)	8.5 (3–18)	16 (6–21)	0.025
Hospital LOS, median (IQR)	18 (7–30)	16 (5–31)	22 (11–30)	0.146
Major complications **				
AKI (%)	15 (9.5)	8 (13.8)	7 (7.0)	0.160
ARDS (%)	17 (10.8)	9 (7.1)	8 (13.8)	0.349
Pneumonia (%)	44 (27.8)	28 (22.2)	16 (27.6)	0.955
DVT (%)	17 (10.8)	10 (7.9)	7 (12.1)	0.686
Sepsis (%)	12 (7.6)	7 (5.6)	5 (8.6)	0.710

* Only patients survived >24 h (n = 163).
** Only patients with hospital LOS >2 days (n = 158).

matched cohort, the use of HAE following HCL was significantly associated with improved patient survival. Trauma centers should be encouraged to have the capability of providing a multidisciplinary team approach in the management of severe liver injury. Further prospective studies to validate the efficacy and determine the indications for early postoperative HAE are still necessary.

AUTHORSHIP

K.M., R.H., A.P., S.B., D.K., S.D., A.S., K.I., D.D. participated in study concept and design. K.M., R.H., A.P., S.B. participated in data collection and analysis. K.M., R.H., A.P., S.B. participated in writing. D.K., S.D., A.S., K.I., D.D. participated in critical revision.

DISCLOSURE

The authors declare no funding or conflicts of interest.

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