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Selective Angiographic Embolization of Blunt Hepatic Trauma Reduces Failure Rate of Nonoperative Therapy and Incidence of Post-Traumatic Complications

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Background: Conflict still remains as to the benefit of angioembolization (AE) for non-operative therapy (NOT) of blunt hepatic trauma (BHT). The aim of this study was to determine whether AE could result in lower failure rates in hemodynamically stable BHT patients with high failure risk factors for NOT, and to systematically evaluate the effectiveness of AE for NOT of BHT.

Material/Methods: Medical records of all BHT patients from January 1, 1998 to December 31, 2015 at a large trauma center were collected and analyzed. Failure of NOT (FNOT) occurred if hepatic surgery was performed after attempted NOT. Logistic regression analysis was used to identify factors associated with FNOT. Hepatobiliary complications related to hepatic trauma during follow-up were reviewed.

Results: No significant difference in FNOT for the no angiographic embolization (NO-AE) group versus angiographic embolization (AE) group was found in hepatic trauma of grades I, II, and V. However, decrease in FNOT was significant with AE performed for hepatic trauma of grades III to IV. Risk factors for FNOT included grade III to IV injuries and contrast blush on CT. Follow-up data of six months also showed that the incidence of hepatobiliary complications in the NO-AE group was higher than the AE group.

Conclusions: Hemodynamically stable BHT patients with grade III to IV injuries, contrast blush on initial CT, and/or decreasing hemoglobin levels can be candidates for selective AE during NOT course.

MeSH Keywords: **Embolization, Therapeutic • Liver • Wounds, Nonpenetrating**

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Background

Non-operative treatment (NOT) is becoming a standard for patients with low-grade (I–III) blunt hepatic trauma (BHT) and in hemodynamically stable condition; and this paradigm shift from operative to non-operative options has been accepted as one of the major clinical advances in the past two decades [1,2]. However, multiple recent trials, series, and systematic literature reviews have reported failure rate of NOT approaching 61.3% to 100% with such factors as age >65 years, high-grade (IV–V) hepatic trauma, contrast blush on computed tomography (CT), cirrhotic condition, more blood transfusion, and higher Injury Severity Scores [3–7]. Over the past decade, the selective application of angiographic embolization (AE) as an adjunct to NOT of hepatic trauma with high failure risk factors has resulted in significant reduction of overall failure rates, and initial post-embolization complication concerns for liver failure or liver abscess have also been minimal [8,9].

Although AE has a good prospect in the treatment of BHT, its actual role and effectiveness remains unclear because of the lack of randomized trials to evaluate AE systematically. Since the foundation of Chinese PLA Air Force Joint-trauma Center in 1997, we have actively used NOT for hemodynamically stable BHT patients, and AE was selectively adopted for those at high risk for failure of NOT (FNOT). The purpose of this study was to test the hypothesis that the addition of AE to standard NOT of hemodynamically stable patients with BHT at high risk for FNOT results in lower failure rates than reported for NOT alone, and to systematically evaluate the effectiveness of AE in the NOT of BHT.

Material and Methods

All medical records of BHT patients from January 1, 1998, to December 31, 2015, at Chinese PLA Air Force Joint-trauma Center were retrospectively collected and analyzed using National Trauma Registry of Chinese Surgery Association. This study was approved by Chinese PLA Air Force Medicine Ethics Committee (Trial Registration Number: 16AGA024), and requirement for patient informed consent was waived for this retrospective study. Exclusion criteria of this study included patients who died shortly after arriving at the hospital, and patients with liver injuries from penetrating trauma or iatrogenic misadventures. Patients who were found to be hemodynamically unstable or who had peritoneal irritation after initial evaluation and were transported directly to the operating room for abdominal exploration were excluded because the operation was mandatory for them. Hepatic trauma was confirmed by contrast-enhanced helical CT. The remaining hemodynamically stable patients with BHT were admitted to an intensive care unit where hemodynamic and abdominal status was monitored. The emphasis of NOT was to keep the cardiocirculatory system stable, which was defined as a heart rate of 60–90 beats per minute (bpm), mean arterial blood pressure of 75–105 mmHg, arterial blood oxygen saturation of >95%, absence of a base deficit >2.5 mmol/L, and urine flow of ≥50 mL/hour [10]. Patients who developed peritonitis and/or hemodynamic instability during NOT were immediately assigned for surgery and defined as FNOT. The extent of hemoglobin decrease used to trigger AE was dependent on the judgment of attending surgeon. For all patients, demographic information, grading of hepatic trauma, presence or absence of contrast blush on initial contrast-enhanced CT, indications for AE, angiographic findings, type of AE, and AE-related hepatobiliary complications were all reviewed. Liver trauma grading referred to the American Association for the Surgery of Trauma classification (revised in 1994) [11].

Although there is still no well-accepted definition of hemodynamic instability, the traditionally accepted value has been a systolic pressure ≤90 mmHg, or patients at risk for hemorrhage and death with a blood pressure ≤110 mmHg [12]. To assist in early triage decisions of BHT, a hemodynamic instability scoring system, which had been proposed for patients with blunt splenic trauma, was also proposed by the Western Trauma Association (WTA) of American to objectively define initial patient hemodynamic status and for subsequent comparisons of management decisions [13,14]. This scoring system was divided into I–V grades of severity of hemodynamic compromise according to the systolic blood pressure (SBP) and response to volume resuscitation, with only grade I–III being less severe and transiently not requiring laparotomy for hemorrhage control.

Two groups of NOT patients were analyzed, those who underwent AE and those with no angiographic embolization (NO-AE). Hepatic AE was performed during the study period only for one or more of the following indications: contrast blush on initial CT, high-grade hepatic trauma of IV to VI, and/or decreasing hemoglobin during NOT observation after admission. FNOT occurred if hepatic surgery was required at any time after NOT was attempted with or without AE. Selective AE was performed using the following techniques [8]. The right-sided femoral approach under digital subtractive angiography (DSA) was accessed. With fluoroscopic guidance, a 5-F reverse curve Mickelson catheter (Cook, Bloomington, IN, USA) was introduced, and the celiac and hepatic arteries were selectively catheterized. Angiography showed extravasation of the contrast medium extending from hepatic arterial branches, and thus, selective embolization was performed by using the micro-catheter system to deploy multiple Tornado coils (Cook) of various sizes into the branches of hepatic artery with follow-up images verifying positioning of the coils. The specific procedure in each patient was at the discretion of the attending

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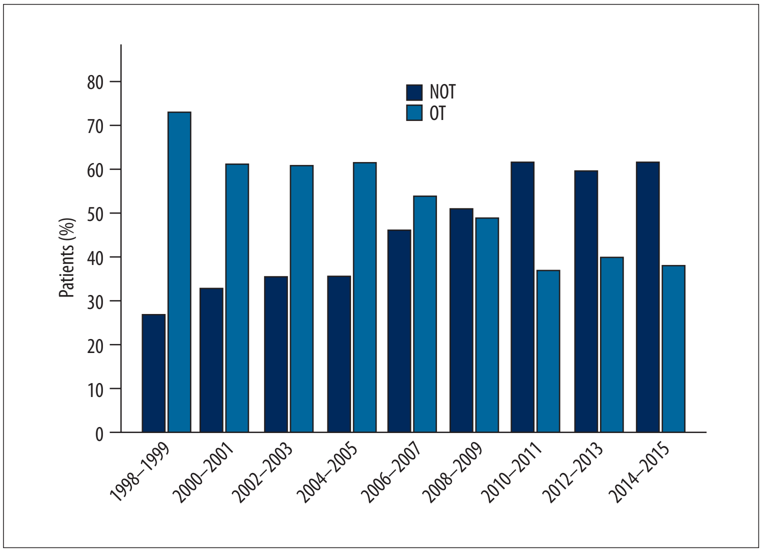

Figure 1. Trends of the therapeutic strategies for BHT over 18 years from 1998 to 2015.

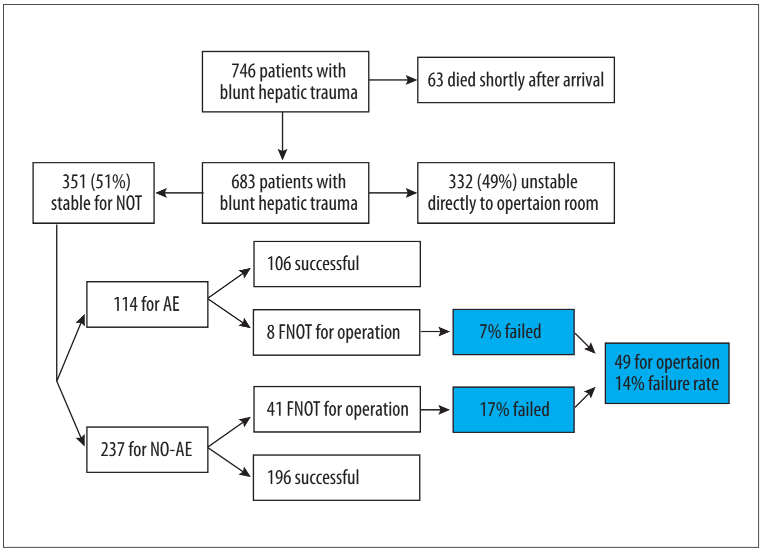

Figure 2. Flow chart of the management of BHT patients.

interventional radiologist. Follow-up imaging was not routinely done unless new symptoms or signs of problems developed. Success of selective AE was defined as absence of active bleeding on the post-embolization angiogram.

This study also included six-month follow-up after discharge. Quantitative data was described as the mean ± standard deviation (SD), and qualitative data as frequency or constituent ratio. Analysis of variance analyzed numerical variables, and Fisher's exact test and chi-square test analyzed categorical variables. Multiple logistic regression analysis, including maximum likelihood estimate for parameter estimation, likelihood ratio test for independent variables selection, and Wald test for the hypothesis test of the regression coefficients, analyzed the effect of AE on successful NOT, as well as independent risk factors for FNOT. A value of $p<0.05$ was considered statistically significant.

Results

Characteristics of patients

There were 746 BHT patients identified from January 1, 1998, to December 31, 2015. The number of patients undergoing NOT gradually increased from 27% to 63% from 1998–1999 to 2010–2011 with transient plateau periods during 2004–2005, and then the numbers remained relatively stable at this level with minor fluctuations. During this time period, there was also a similar but opposite trend for the percent of patients who underwent operative treatment (OT) proportionally (Figure 1). Sixty-three patients died shortly after arrival, 332 patients were directly sent for operation because of hemodynamic instability or gastrointestinal rupture. These 395 patients were all excluded. The remaining 351 hemodynamically stable patients underwent NOT, including NO-AE (237 patients), and AE

Table 1. Demographic and clinical variables according to treatment group.

Variable	Operation (n=332)	NOT NO-AE (n=237)	NOT AE (n=114)	Overall p-value*	P-value AE *vs.* NO-AE
Gender (n,%)				0.28	0.17
Male	229 (69)	151 (64)	81 (71)		
Female	103 (31)	86 (36)	33 (29)		
Age (year)	39.4±14.6	38.5±15.3	38.7±16.1	0.76	0.91
NISS	41±16	22±13	30±14	<0.01	<0.01
Low grade (I–III)	82 (25%)	193 (81%)	87 (76%)	<0.01	0.26
High grade (IV–VI)	250 (75%)	44 (19%)	27 (24%)		
Admission SBP	98±31	122±29	113±20	<0.01	<0.01
Mortality	63 (19%)	21 (9%)	13 (11%)	<0.01	0.45
Hospitalization time (day)	27±13	22±9	15±6	<0.01	<0.01
Injury cause				0.66	0.73
MVC	142 (43%)	91 (38%)	47 (41%)		
Motorcycle crash	57 (17%)	49 (21%)	22 (19%)		
Pedestrian *vs.* auto	21 (6%)	18 (8%)	9 (8%)		
Fall from height	73 (22%)	46 (19%)	25 (22%)		
Sport injury	12 (4%)	4 (2%)	3 (3%)		
Military training	27 (8%)	29 (12%)	8 (7%)		

NISS – New Injury Severity Score; MVC – motor vehicle crash. * Overall *P* value of the comparison between Operation group *vs.* AE group *vs.* NO-AE group.

(114 patients). Of these patients, 41 (17.3%) NO-AE patients had FNOT and eight (7.0%), AE patients had FNOT with a total rate of FNOT of 14.0% (49/351) (Figure 2). Demographics, clinical characteristics, and trauma cause of these three groups (OT, NO-AE, and AE) were compared. Only higher New Injury Severity Score (NISS), proportion of high-grade hepatic trauma (IV–VI), and mortality, lower admission SBP rate, and longer hospitalization time in OT versus NOT groups were indicated. Comparison of AE versus NO-AE indicated that AE group contained higher NISS, greater percent of high-grade liver trauma, and shorter hospitalization time, while they were otherwise similar (Table 1).

Efficacy of AE and NO-AE in NOT of BHT

FNOT of the NO-AE group versus the AE group were compared according to the hepatic trauma grading (Table 2). Although such factors as male, age, high-grade hepatic trauma proportion, and trauma cause were matched well in the NO-AE and the AE groups, a significant decrease from 47.7% to 18.5% was found in FNOT with the additional use of AE for high-grade hepatic trauma (5/27 versus 21/44, $p<0.01$). Although FNOT decreased from 28.6% to 6.3% in BHT patients of grade III, no statistical difference was found in overall FNOT for low-grade hepatic trauma (3/87 versus 20/193, $p>0.05$).

There were 114 AE patients. The indication for AE was contrast blush on contrast- enhanced CT (41 patients [36.0%]), an episode of hypotension or decreased hemoglobin levels during NOT (36 patients [31.6%]), high-grade hepatic trauma of IV to VI as demonstrated by CT (22 patients [19.3%]), and required angiogram for concurrent spleen or aorta injury (15 patients [13.2%]). Of the 41 AE for contrast blush, five (12.2%) also had high-grade hepatic trauma of IV to V and therefore had dual indications for AE. All 36 AE for an episode of hypotension or decreased hemoglobin level were low-grade hepatic trauma of I to III. These patients underwent AE during the 12–45 hours of NOT observation based on the rate of mean arterial blood pressure decrease and/or hemoglobin level decrease during serial evaluations. The mean starting mean arterial blood pressure was 113 mmHg and hemoglobin level was 11.3, and mean ending mean arterial blood pressure before AE

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Table 2. Comparison of failure rates of NOT for NO-AE *vs.* AE based on AAST grading of hepatic trauma.

Grade	NO-AE		AE		*p*
	Patients (No.)	Failed (%)	Patients (No.)	Failed (%)	
I	71	1	21	0	1.00
II	66	5	34	3	0.88
III	56	29	32	6	0.01
IV	26	35	15	0	0.01
V	18	56	11	36	0.45
*p**		<0.01			<0.01
Total	**237**	**17**	**114**	**7**	**0.01**

* Comparison of the failure rate in NO-AE group and AE group calssified by trauma grading.

was 85 mmHg and hemoglobin was 6.7. The range of mean arterial blood pressure was 73 mmHg to 128 mmHg, and hemoglobin was 12.4 to 6.1. Angiography revealed multiple extravasations during the early arterial phase involving segment I in two (1.8%) patients, segment II in nine (7.9%), segment III in 12 (10.5%), segment IV in 14 (12.3%), segment V in 31 (27.2%), segment VI in 25 (21.9%), segment VII in 28 (24.6%), and segment VIII in 36 (31.6%). No patient had active extravasation from the hepatic trunk in the early arterial phase. The late arterial phase depicted active extravasation from the proximal left hepatic artery in six patients (5.3%), and from the proximal right hepatic artery in 11 patients (9.6%). Neither bleeding from the juxtahepatic veins nor supplementary contrast pooling was found during the portal phase. Simple selective embolization involving the arterial branches (SSEAB) was done in 85 patients (74.6%) by coaxial microcatheter, of whom 61 (71.8%) underwent super-selective embolization (embolization of the terminal branches of the bleeding intrahepatic artery). Combined embolization involving the extrahepatic trunk and intrahepatic branches (CEETIB) was done in 29 patients (25.4%) by using metal and coaxial micro-coils. Figures 3–5 show the CT and selective AE images of BHT patients (grade III to V). Although 59 patients in the NO-AE group met the criteria for AE, including contrast blush (15 patients[6.3%]) and high-grade hepatic trauma of IV to VI (44 patients[18.6%]), they did not undergo AE for various reasons based on the attending surgeon's decision, and 33 (55.9%) had FNOT A significantly lower FNOT was found after AE versus NO-AE for contrast blush-positive and high-grade hepatic trauma patients (6/63 versus 33/59, $p<0.001$).

The average hospital time that FNOT occurred for all 49 failures was 38.3 hours (range, 4–137 hours). In the NO-AE group, 21 (51.2%) patients of the 41 FNOT patients had high-grade BHT and decreasing hemoglobin, 16 (39.0%) patients were hemodynamically unstable (WTA scoring system of grade III–V and hepatic trauma of grade II–III) on admission, and four (9.8%) patients developed peritonitis during NOT. Of the 15 patients in the NO-AE group who had clear contrast blush, 12 patients failed within 72 hours of NOT observation (two of grade II and 10 of grade III). In the AE group, five of the eight had FNOT (one of grade III, three of grade V, and one of grade VI) were hemodynamically unstable on admission (WTA scoring system of grade III–V), two (one of grade II and one of grade III) developed peritonitis after AE (WTA scoring system of grade II–III), and the remaining one FNOT patient with BHT of grade IV (WTA scoring system of grade III) was appropriately sent for AE based on contrast blush on contrast-enhanced CT became hemodynamically unstable and thus emergent laparotomy was performed. For the patient of grade VI BHT in the AE group, the hepatic trauma had been underestimated as grade IV after CT scan. The patient was sent for AE six hours after admission because of multiple episodes of SBP <90 mmHg despite four units of red blood cells and four units of plasma transfusion. This patient's angiography showed hepatic avulsion and the attending surgeon was immediately aware of the severity. Then emergent operation of right hepatic resection was performed. Multiple logistic regression analysis showed that hepatic trauma of grade IV to V and the presence of contrast blush or pooling of contrast material within the liver parenchyma were statistically significant independent risk factors ($p<0.05$) for FNOT (Table 3). Odds ratio calculations show that hemodynamically stable patients with a contrast blush or pooling of contrast material within the liver parenchyma have a 13.1 times greater likelihood of FNOT if they are observed without AE (95% confidence interval: 5.2<17.3<52.6), and grade IV–V injuries have a 3.7 times greater likelihood of FNOT with observation and NO-AE (95% confidence interval: 0.9<4.1<11.5).

Follow-up outcome

Follow-up of six month after discharged from hospital was given to all NOT patients. There were 34 deaths among the

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Figure 3. AE for BHT of grade III. (**A**) Subcapsular hematoma >50% surface area (arrow). (**B**) Hepatic laceration (white arrow) >3 cm and intrahepatic hematoma in segment IV and V (black arrows). (**C**) Angiography showing active multi-intrahepatic bleeding. (**D**) Comlpete bleeding control after AE.

351 NOT patients (9.7%), and no difference was found in the mortality rates between the AE group and the NO-AE group (Table 1). Only three deaths, including two in the NO-AE group and one in the AE-group, were directly attributable to hepatic trauma (0.9% of all NOT patients, 8.8% of all NOT deaths). The two dead patients in the NO-AE group (one of grade IV, and the other one of grade V) refused operation because of serious concerns about their cirrhosis and older age (>75). A patient with grade VI in the FNOT-AE group died of hemorrhagic shock and hepatic failure five days after their operation. All other deaths were due to trauma complications of multiple systems. Seventeen patents in the NO-AE group and five patients in the AE-group were lost due to various reasons during the follow-up period. FNOT, deaths, and lost patients in the NOT group were all excluded from the follow-up data analysis.

Hepatobiliary complications

Among the remaining 158 patients in the NO-AE group, 47 (29.7%) developed various BHT-related hepatobiliary complications, including hepatic or perihepatic abscess in 22, liver necrosis in six, and biliary complications such as biloma, bile leak and bile peritonitis in 19. Twenty-eight patients (17.7% of the NO-AE group and 59.6% of the patients with BHT-related hepatobiliary complications) were managed by image-guided percutaneous drainage or endoscopic retrograde cholangiopancreatography (ERCP), of whom six patients had laparoscopic drainage because of failure of percutaneous drainage. Two patients had hepatic resection because of recurrent or complex liver complications. Among the remaining 89 patients in the AE group, nine (10.1%) developed AE or BHT-related hepatobiliary complications, including liver necrosis in three, hepatic abscess in one, gallbladder infarction in two, and biliary complications in three. Complications occurred in two patients

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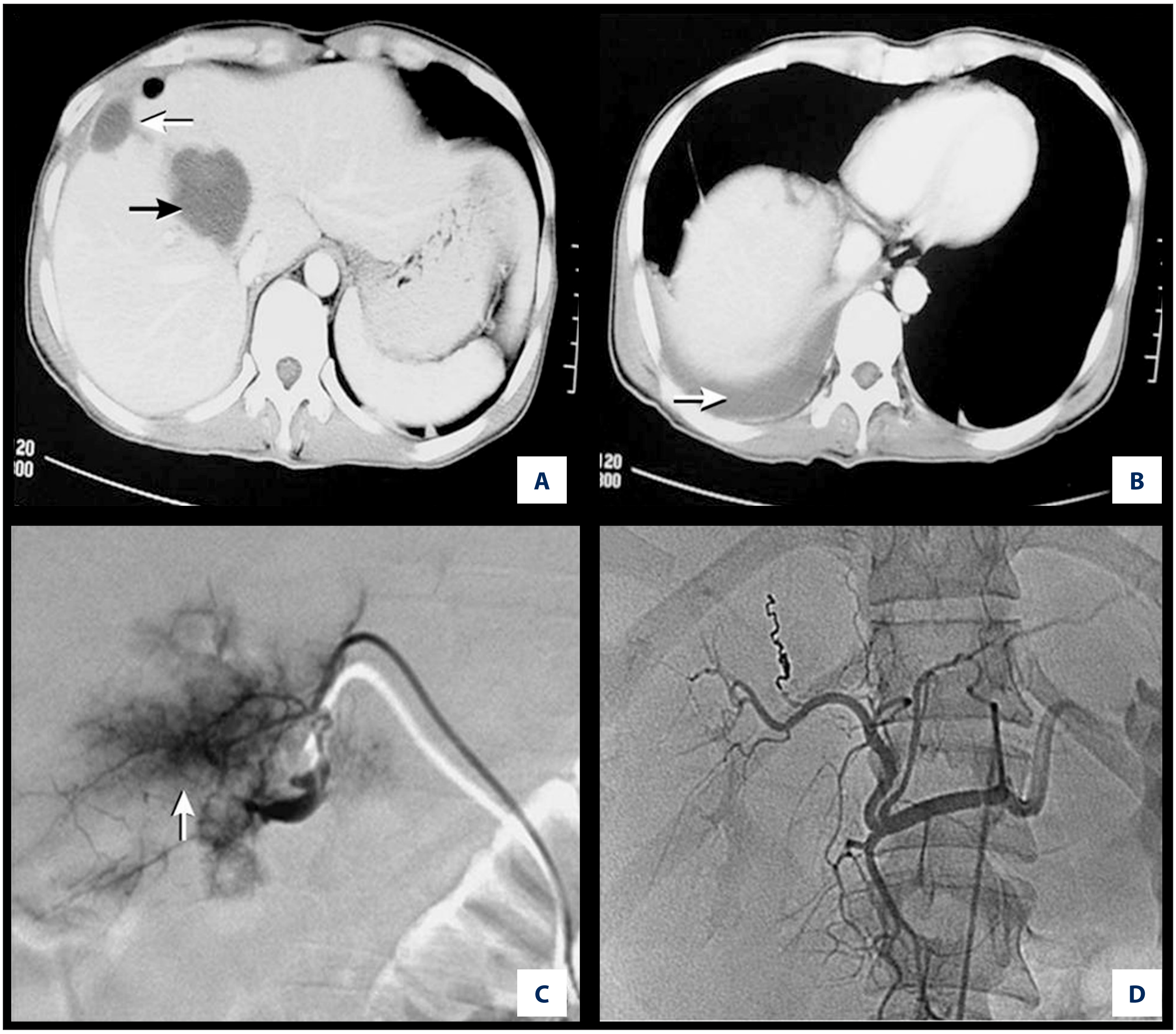

Figure 4. AE for BHT of grade IV. (**A**) Parenchymal disruption involving segment VIII (white arrow) and VII (black arrow); (**B**) Active extravasation around right liver lobe; (**C**) Angiography showing active intrahepatic arterial bleeding in segment VII and VIII (white arrow); (**D**) Complete bleeding control after selective coil embolization.

after SSEAB and in seven patients after CEETIB. Seven patients (7.9% of the patients in the AE group and 77.8% of patients with AE- or BHT-related complications) were managed by invasive therapy, including image-guided percutaneous drainage, laparoscopic drainage, and laparoscopic cholecystectomy. Incidence comparison of the hepatobiliary complications related to BHT or AE of the NO-AE group versus the AE group indicated that AE was lower than NO-AE ($p<0.01$).

Discussion

In recent years, the potential of AE to improve the success rate of NOT has been reported more and more often; however, the actual benefit and exact indications remain unclear even in some well-known trauma centers [15,16]. In our center, all surgeons adopted and closely followed protocols for selective use of AE for BHT patients with high risks, for purposes of diagnosis and therapy, which contributed not only to the steady rise in proportion of OT (37–40%) versus NOT (60–63%) since 2010, but also to the steady annual growth rate (25–30%) for AE adopted in treatment of BHT patients since 2006. Although AE did not decrease the FNOT rate of grade V, it helped to evaluate the hepatic trauma accurately, and helped surgeons make decisions in NOT, and determine the appropriate operation mode. The FNOT rate of this study was 14.0%, lower than the rate of 30–40% reported by Trauma Society of Chinese Medical Association (TSCMA) in 2010 [17]. Because AE had not been widely adopted in earlier studies conducted by TSCMA, we suggest that selective

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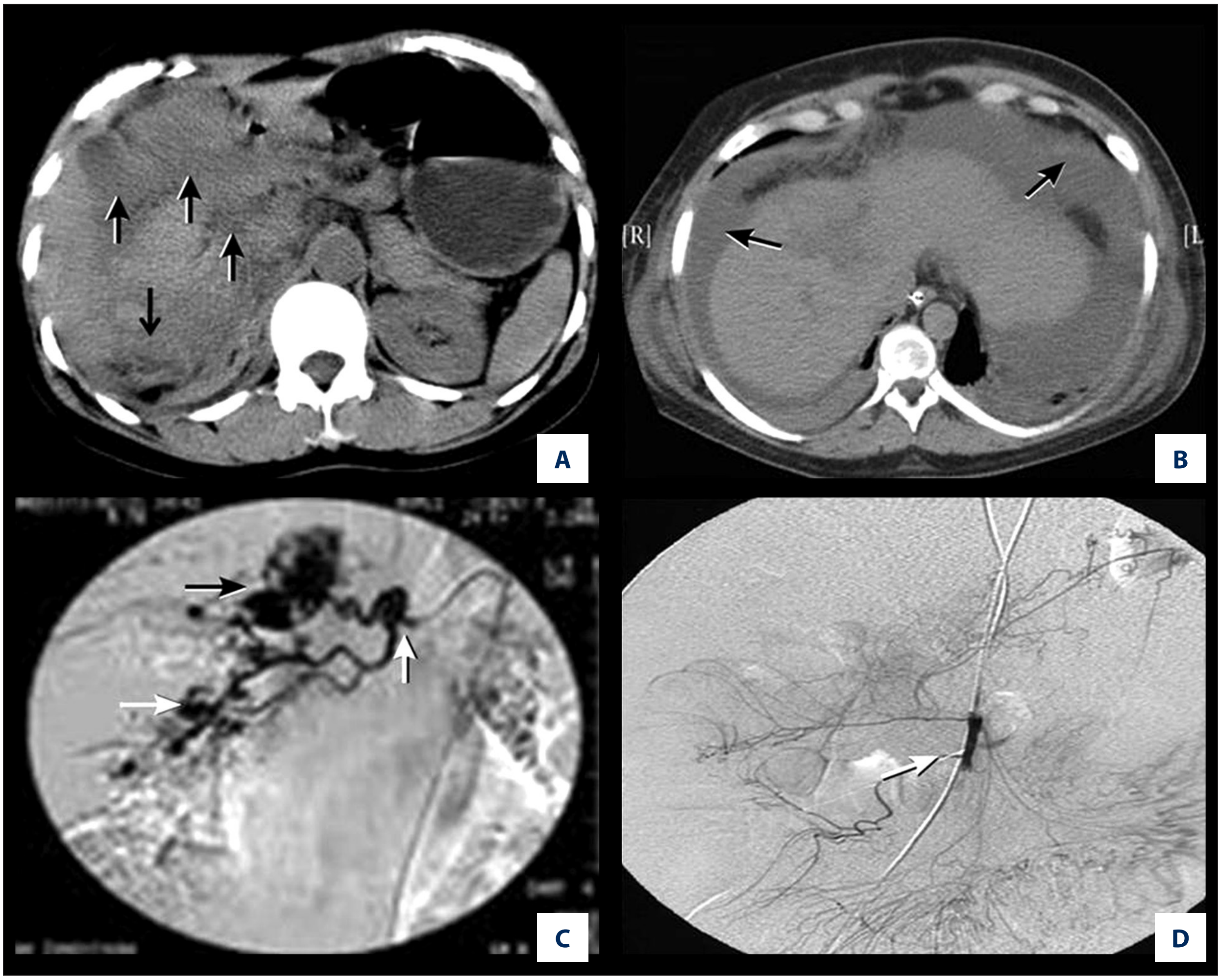

Figure 5. AE for BHT of grade V. (**A**) Parenchymal disruption involving >75% of right lobe (arrows); (**B**) Large amount of active exudationt around the liver (arrows); (**C**) Intrahepatic bleeding from segment VII (black arrows), VI (white horizontal arrow), and VIII (white vertical arrow); (**D**) Complete bleeding control after AE of the right lobe artery (white arrow).

adoption of AE and appropriate selection of BHT patients were the two major factors contributing to the significant decrease of FNOT. Although the mortality of FNOT in hepatic trauma was reported to approach 50% in a multi-institutional study conducted by University of Pittsburgh Medical Center from 2002 to 2008 [18], only one patient with FNOT of grade V (grade VI after angiographic evaluation) from the NOT group died after AE and operation in this study, and no serious complications occurred.

We thus emphasize three factors as the protocol for successful treatment of emergent BHT: 1) hemodynamically unstable patients should have the operation without any delay; 2) contrast blush on initial enhanced CT scan, hepatic trauma above grade III on initial CT, and/or decreasing hemoglobin levels during NOT observation are high risk factors of FNOT, and AE should be selectively used for such patients rather than universally for all BHT patients; and 3) under close monitor, delayed AE can be safely performed to salvage decreasing hemoglobin levels in those hemodynamically stable patients.

The most important principle which must be followed in NOT of BHT is that instability of hemodynamics is an absolute contraindication and patients require immediate surgery for hemorrhage control as quick as possible. In this retrospective evaluation, 16 of the 41 FNOT patients in the NO-AE group and five of the eight FNOT patients in the AE group were hemodynamically unstable by the WTA scoring criteria during their initial admission resuscitation. WTA scoring above grade III might have predicted the result of FNOT in these patients, and in theory, they should have had the surgery. However, these patients were all transiently responsive to initial NOT, especially in patients of WTA scoring system grade III, the response was more obvious and lasted longer, and for which the ill-guided decision of NOT was made, demonstrating the importance of relying on the overall condition of the patient rather than single blood pressure readings in

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Table 3. Characteristics of FNOT patients (NO-AE *vs.* AE).

Age	Sex	Initial SBP	Grade	Injury cause	FNOT hour	CB on CT
NO-AE						
64	M	115	I	Fall	78	No
25	M	***100***	II	MT	26	Yes
29	F	115	II	MVC	60	No
43	M	120	II	MVC	48	Yes
31	M	112	III	MVC	40	Yes
34	F	***105***	III	MC	22	Yes
25	M	128	III	SPORT	50	No
54	M	120	III	MVC	34	Yes
27	F	125	III	PED	30	No
16	M	108	III	MC	18	Yes
39	M	122	III	MVC	29	Yes
30	M	130	III	FALL	36	Yes
22	M	120	III	MT	80	No
46	M	122	III	MVC	46	No
40	M	130	III	MVC	52	Yes
35	M	125	III	MVC	62	Yes
62	F	110	III	MVC	40	No
36	M	***100***	III	MVC	24	Yes
52	F	115	III	MVC	42	No
23	M	***107***	III	FALL	35	Yes
45	M	115	IV	FALL	72	Yes
55	M	***95***	IV	MVC	64	No
38	F	115	IV	MVC	48	Yes
42	M	126	IV	MC	90	Yes
36	M	***95***	IV	MVC	18	No
27	M	***103***	IV	MVC	20	Yes
33	M	***100***	IV	MVC	24	Yes
51	F	112	IV	MC	43	No
25	M	***105***	IV	MVC	30	Yes
39	M	125	IV	MVC	40	No
28	M	***107***	IV	MC	29	Yes
66	F	116	V	MVC	80	Yes
39	M	110	V	MVC	40	Yes
44	F	***95***	V	MC	30	Yes

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Table 3 continued. Characteristics of FNOT patients (NO-AE *vs.* AE).

Age	Sex	Initial SBP	Grade	Injury cause	FNOT hour	CB on CT
34	M	***100***	V	MVC	24	Yes
19	M	***95***	V	SPORT	22	No
21	M	116	V	MVC	44	Yes
36	M	110	V	MVC	40	No
23	F	***105***	V	PED	24	Yes
34	M	***97***	V	MVC	33	Yes
29	M	118	V	MVC	30	Yes
AE						
41	M	125	II	MVC	72	No
25	M	***105***	III	MVC	20	Yes
32	F	110	III	MC	48	Yes
50	M	***102***	V	MVC	30	Yes
29	M	***100***	V	FALL	32	Yes
38	M	115	V	SPORT	35	Yes
28	F	***95***	V	MVC	28	Yes
43	M	***85***	VI	FALL	8	Yes

MT – military training; MVC – motor vehicle crash; MC – motorcycle crash; PED – pedestrian *vs.* auto. Highlighted cells show inappropriate criteria for NOM.

making decisions. The higher NISS of the AE group compared to the NO-AE group (Table 1) was partially due to the inclusion of the inappropriately selected NOT patients, but it also objectively reflected the much more severe injuries in the AE group. So it must be emphasized to surgeons making a decision regarding NOT that AE should not be considered a valid treatment option for BHT patients in hemodynamically unstable conditions.

Huang et al. [7] documented the dangers of delayed operation for FNOT of BHT because of poor patient selection in the TSCMA Multicenter study. For patients above grade III in hemodynamic instability, the added risk of coagulopathy and multi-organ failure was 25%; and 17.5% had liver-related mortality. The mortality rate was 31% among the unstable patients, and an undue delay in laparotomy was responsible for 45% of the deaths, while the mortality rate was only 5% among stable patients.

There were 13/49 (26.5%) of FNOT patients in this study who failed within the first 24 hours of observation. Three of our 21 unstable FNOT patients died of liver-related coagulopathy and multi-organ failure. This 14.3% (3/21) of liver-related mortality among our unstable NOT patients was obviously lower than the 31% mortality rate among unstable NOT patients reported by Huang et al. Our result was perhaps attributable to our heightened alertness to hemodynamic instability and the control of bleeding by AE. However, it also demonstrated the preventability of such deaths and the importance of adhering to strict selection criteria to optimize the safety of NOT for BHT. In fact, NOT has also been regarded as important for various gastrointestinal traumas, and risk predictors in this field can help us avoid failed delay for BHT patients under NOT. For example, bowel wall thickening in CT predicts correlated organ injury, and increased levels of MMP-1-2-9-13 or decreased levels of TIMP-1-2-3 may reflect severe systemic disease [19,20].

Another lesson came from the only patient of grade VI in the AE and NO-AE groups who had been transfused with four units of packed red blood cells before AE and then quickly failed to maintain blood pressure. This patient had been underestimated as grade IV during the initial evaluation and eventually died because of this error in evaluation. Although there is no established consensus on how blood transfusion should be mandated related to the decision to operate, Prichayudh et al. [21] and Huang et al. [7] suggest that the need to transfuse a patient for low hematocrit was in itself a deciding indication for exploratory laparotomy, and 3.5 units of red blood cells transfusion was the "threshold" volume that should be accepted for NOT of BHT above grade III.

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AE should be applied in a selective manner based on high-risk factors for FNOT, including contrast blush on initial CT, high-grade hepatic trauma of IV–VI, and/or decreasing hemoglobin levels during NOT observation, rather than universally applied to all BHT patients. Celiac and mesenteric arteriography allows localization of a blush and performance of AE. Altogether 114 hemodynamically stable BHT patients undergoing NOT in this study underwent AE, with the majority of them undergoing simple selective embolization and minimal use of combined embolization. In this study, the liver salvage rate was 88.6% and the overall FNOT rate of 14.0% has been one of the lowest ever reported. Sixty-nine of the 114 BHT patients (60.5%) had positive angiograms and underwent AE. Forty-five (39.5%) patients had negative angiograms, which seemed to have been unnecessary because the majority of them (41/45, 91.1%) had low-grade trauma of I-II, and the FNOT rate of those patients was 0% with just simple observation. Correspondingly, we found in this study that patients with hepatic trauma of grade I to II had no significant decrease in the FNOT rate after AE while those with grades III to IV had an obvious decrease (32.9% to 4.3%, $p<0.01$). For hepatic trauma above grade V with the high incidence of associated abdominal organ injuries, the FNOT rates did not decrease after AE, although Rosemary et al. [22] reported from the data National Trauma Data Bank that 62.6% of grade V injuries were successfully managed without operative intervention; the rate in our study was (63.6% [7/11]). On the basis of these data, we recommend routine AE for all hepatic trauma of grade III to IV, regardless of any other finding; and selective AE for grades of I, II, and V only if they manifest contrast blush and/or decreasing hemoglobin levels during NOT observation.

Misselbeck et al. [23] reported in 2009 an aggressive hepatic angiography (HA) and hepatic angioembolizaiton (HAE) protocol that resulted in successful NOT for 79 patients of whom more than 80% had grade III to IV hepatic injury. The authors compared their approach with other contemporary similar research involving large samples and concluded that although the results were nearly the same, only minimal performance of angiography was found for low-grades of I and II injuries which therefore resulted in the maximal embolization rate. Furthermore, they advocated the protocol for HAE as a first-choice additional use in those with grade III to V and/or vascular injuries as a result of these findings. Similarly, we found in this study that 58 patients in the AE group had grade III to V injuries, of which six were FNOT (10.3%), for a success rate of 84%. We agree with the viewpoint proposed by Misselbeck et al. [23] with the additional recommendation that AE should be performed in all NOT patients with grade III to V trauma.

The finding of a "blush" or pooling of intravenous contrast material within the liver parenchyma, on initial CT is always connected with active hemorrhage. Earlier studies suggested operative intervention for such patients regardless of hemodynamic stability, though the availability of AE may have successfully managed the hemorrhage, because the presence of contrast blush itself is a poor prognostic indicator resulting in increased FNOT rates [24]. In our study, we found a 13-fold increased FNOT for BHT patients with contrast blush on initial CT, similar to the Petrowsky et al. study that found 15 times the likelihood of FNOT, and concluded that the combination of contrast blush with high grade hepatic trauma (IV to V) was a contraindication to NOT [25]. In our study, three patients in the NO-AE group with this combination undergoing NOT all failed; however, of the five patients in the AE group with this combination, only one failed. Our data supports that the additional usage of AE to NOT of BHT has a distinct benefit in allowing the safe extension of NOT to those high-risk groups that previously were not considered for this option.

Our data further showed that AE can be performed safely by means of a delayed manner in NOT of BHT patients who remain hemodynamically stable but have an episode of hypotension or decreasing hemoglobin levels. We had 36 such patients who had no contrast blush during initial CT evaluation and all (100%) were salvaged with the hemoglobin stabilizing immediately after AE. Interestingly, all of these patients were low-grade (I–III) hepatic trauma, so decreasing hemoglobin in hemodynamically stable patients without contrast blush on CT should be regarded as an absolute indication for AE alone.

Not surprisingly, because more aggressive NOT is being pursued and CT is used more routinely during follow-up, more liver-related complications are being diagnosed. Complications are primarily related to the grade of hepatic trauma and the need for transfusion, and reported complication rates range from 10–25% when all grades are considered, but can be as high as 30–35% when only high-grade traumas are considered [15]. In this study, the complication rate of successful NOT was 22.7% (56/247), including 29.7% (47/158) in the NO-AE group and 10.1% (9/89) in the AE-group. It can be inferred from the data that AE contributes primarily to the decrease in complication rates. The type of AE (SSEAB versus CEETIB) may provide some insight into why both the FNOT and complication rates have been decreased. More and more evidence is showing that SSEAB can result in less complications and a higher success rate of NOT than CEETIB [8,13]. In SSEAB, the bleeding intrahepatic arterial branches are target embolized, resulting in decreased blood flow and lower hepatic blood pressure of the injured segment, which facilitates clot formation and hemostasis, while still allowing the blood flow of extrahepatic trunk to maintain liver viability. Seventy-five percent of the patients in this study underwent SSEAB (including super-selective embolization), and another 25% had CEETIB. The evolution of AE techniques plays an important role in achieving the high success rates and low complication rates in NOT of BHT. From our experience, the AE-related hepatobiliary complications are unavoidable, but the incidence and severity can

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be lowered by selective or super-selective embolization of the intrahepatic arterial branches.

Conclusions

The addition of AE to the treatment of BHT was found safe and effective through applying strict defined criteria, which contributed to the low failure rate of FNOT (14.0%) and low mortality (0.9%). This study showed that hemodynamically stable BHT patients can undergo NOT safely and that the indications for, and success of, NOT for BHT can be extended through the selective application of AE to defined high-risk groups.

References:

1. Hommes M, Navsaria PH, Schipper IB et al: Management of blunt liver trauma in 134 severely injured patients. Injury, 2015; 46: 837–42
2. Sivrikoz E, Teixeira PG, Resnick S et al: Angiointervention: An independent predictor of survival in high-grade blunt liver injuries. Am J Surg, 2015; 209: 742–46
3. Chien LC, Lo SS, Yeh SY: Incidence of liver trauma and relative risk factors for mortality: A population-based study. J Chin Med Assoc, 2013; 76: 576–82
4. Beuran M, Nego I, Ispas AT et al: Nonoperative management of high degree hepatic trauma in the patient with risk factors for failure: Have we gone too far? J Med Life, 2010; 3: 289–96
5. van der Vlies CH, Saltzherr TP, Wilde JC et al: The failure rate of nonoperative management in children with splenic or liverinjury with contrast blush on computed tomography: a systematic review. J Pediatr Surg, 2010; 45: 1044–49
6. Lin BC, Fang JF, Wong YC et al: Management of cirrhotic patients with blunt abdominal trauma: analysis of risk factor of postoperative death with the Model for End- Stage Liver Disease score. Injury, 2012; 43: 1457–61
7. Huang YC, Wu SC, Fu CY et al: Tomographic findings are not always predictive of failed nonoperativemanagement in blunt hepatic injury. Am J Surg, 2012; 203: 448–53
8. Kong YL, Zhang HY, He XJ et al: Angiographic embolization in the treatment of intrahepatic arterial bleeding in patients with blunt abdominal trauma. Hepatobiliary Pancreat Dis Int, 2014; 13: 173–78
9. Letoublon C, Morra I, Chen Y et al: Hepatic arterial embolization in the management of blunt hepatic trauma: Indications and complications. J Trauma, 2011; 70: 1032–36
10. Kong Y, Zhang H, He X et al: Endoscopic management for pancreatic injuries due to blunt abdominal trauma decreases failure of nonoperative management and incidence of pancreatic-related complications. Injury, 2014; 45: 134–40
11. Homann G, Toschke C, Gassmann P, Vieth V: Accuracy of the AAST organ injury scale for CT evaluation of traumatic liver and spleen injuries. Chin J Traumatol, 2014; 17: 25–30
12. Kozar RA, Moore FA, Moore EE et al: Western Trauma Association critical decisions in trauma: Nonoperative management of adult blunt hepatic trauma. J Trauma, 2009; 67: 1144–48
13. Kozar RA, Feliciano DV, Moore EE et al: Western Trauma Association/critical decisions in trauma: Operative management of adult blunt hepatic trauma. J Trauma, 2011; 71: 1–5
14. Moore FA, Davis JW, Moore EE Jr. et al: Western Trauma Association (WTA) critical decisions in trauma: Management of adult blunt splenic trauma. J Trauma, 2008; 65: 1007–11
15. Li M, Yu WK, Wang XB et al: Non-operative management of isolated liver trauma. Hepatobiliary Pancreat Dis Int, 2014; 13: 545–50
16. Bellemann N, Sommer CM, Mokry T et al: Hepatic artery stent-grafts for the emergency treatment of acute bleeding. Eur J Radiol, 2014; 83: 1799–803
17. Zong ZW, Li N, Cheng TM et al., Group for Trauma Emergency Care and Multiple Injuries, Trauma Society of Chinese Medical Association: Current state and future perspectives of trauma care system in mainland China. Injury, 2011; 42: 874–78
18. Polanco PM, Brown JB, Puyana JC et al: The swinging pendulum: A national perspective of nonoperative management in severe blunt liver injury. J Trauma Acute Care Surg, 2013; 75: 590–95
19. Isik A, Soyturk M, Süleyman S et al: Correlation of bowel wall thickening seen using computerized tomography with colonoscopies: A preliminary study. Surg Laparosc Endosc Percutan Tech, 2017; 27(3): 154–57
20. Isik A, Peker K, Aydın M et al: Metalloproteinases and their inhibitors in patients with inguinal hernia.World J Surg, 2017; 41: 1259–66
21. Prichayudh S, Sirinawin C, Sriussadaporn S et al: Management of liver injuries: Predictors for the need of operation and damage control surgery. Injury, 2014; 45: 1373–77
22. Kozar RA, Moore FA, Moore EE et al: Western Trauma Association critical decisions in trauma: nonoperative management of adult blunt hepatic trauma. J Trauma, 2009; 67: 1144–49
23. Misselbeck TS, Teicher EJ, Cipolle MD et al: Hepatic angioembolization in trauma patients: Indications and complications. J Trauma, 2009; 67: 769–73
24. Chien LC, Lo SS, Yeh SY: Incidence of liver trauma and relative risk factors for mortality: A population-based study. J Chin Med Assoc, 2013; 76: 576–82
25. Petrowsky H, Raeder S, Zuercher L et al: A quarter century experience in liver trauma: A plea for early computed tomography and conservative management for all hemodynamically stable patients. World J Surg, 2012; 36: 247–54

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