Observational Study

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Characteristics of computed tomography in hemodynamically unstable blunt trauma patients

Experience at a tertiary care center

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Abstract

Emergent exploratory laparotomy is recommended for hemodynamically unstable blunt trauma patients suspected of having hemoperitoneum. However, given the unreliability of ultrasonography and rapid scan speed of computed tomography (CT), CT might help clinicians provide accurate information even in hemodynamically unstable trauma patients. This observational study aimed to describe the bleeding site and hospital course of severe blunt trauma patients with hemoperitoneum diagnosed by CT scan.

We enrolled all consecutive adult blunt trauma patients (≥18 years old) who underwent whole-body CT before operation between February 2012 and October 2016. Patients with hemoperitoneum on CT images were included and categorized into hemodynamically stable and unstable (persistent hypotension despite fluid resuscitation) groups.

Among 1723 severe blunt trauma patients, 136 patients with hemoperitoneum were included. Of these, 98 (72.1%) patients had documented intraperitoneal injury, and the liver (60.2%) was most frequently damaged site, followed by spleen (23.5%) and mesentery (23.5%). The rate of intraperitoneal organ injury did not differ between hemodynamically stable (n = 107) and unstable (n = 29) groups (69.2% vs 82.8%, $P = .15$), while the documented active internal bleeding was high in the unstable group (29.9% vs 69.0%, $P < .001$). In the unstable group, 14 (48.3%) patients underwent emergent operation, while 3 patients underwent embolization, and the others were treated in a conservative manner.

Even in hemodynamically unstable hemoperitoneum patients, 17.2% had no documented intraperitoneal injury and over half of the patients were treated without emergent operation.

Abbreviations: ATLS = Advanced Trauma Life Support, CI = confidence interval, CT = computed tomography, ED = emergency department, FAST = Focused Assessment with Sonography in Trauma, ISS = Injury Severity Score, OR = odds ratio, RTS = Revised Trauma Score.

Keywords: hemoperitoneum, multidetector computed tomography, trauma

1. Introduction

Prompt assessment and accurate diagnosis of intraabdominal injury is essential to ensure a favorable outcome in severe blunt trauma patients. For more than 2 decades, the Focused Assessment with Sonography in Trauma (FAST) examination has been recommended for the initial assessment of blunt trauma patients, particularly for those presenting with hemodynamic instability at the emergency department (ED).[1–3] Several guidelines recommend that patients with intraabdominal fluid on FAST examination should be transferred to the operating room for exploratory laparotomy.[2,4]

The treatment algorithms are controversial, including the poor diagnostic reliability of FAST and the considerable number of cases wherein exploratory laparotomy is unnecessarily performed.[5–7] Recent studies showed that hypotension in abdominal blunt trauma patients, even in those with positive FAST examination results, is not always indicative of active bleeding in the intraperitoneum or hypovolemic shock.[6,7] Moreover, the importance of contrast-enhanced computed tomography (CT) in the evaluation of trauma patients is becoming gradually understood, not only due to its increased diagnostic indications but also due to its increased availability and the improved speed of the CT scanner.[8–11] Embolization is also an important therapeutic option in some trauma patients. On the basis of these findings, further discussion of the use of CT before exploratory laparotomy in hemodynamically unstable patients with trauma is needed.

We hypothesized that CT might be helpful in ensuring the accurate detection of organ injury and in guiding optimal therapeutic decision-making even in hemodynamically unstable patients with blunt trauma, despite the potential risks. Accordingly, we aimed to identify the location of injuries in hemodynamically unstable and stable patients with blunt trauma,

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and assess whether emergent laparotomy or interventions are required; compare the management (conservative treatment, embolization, or surgery) and outcome of these patients; and evaluate the rate of adverse events during CT scans.

2. Materials and methods

2.1. Study design and population

This retrospective cohort study was conducted at a tertiary care center located in an urban area. Approximately 100,000 patients are treated per year at our ED. Before study initiation, approval was obtained from our institutional review board, which waived the requirement for informed consent due to the retrospective nature.

At our institution, emergency physicians notified the trauma team upon the arrival of severe blunt trauma patients who presented with unstable vital signs or had been injured through high-risk mechanisms. The initial assessment and treatment were performed cooperatively in accordance with Advanced Trauma Life Support (ATLS) guidelines of 2008 and 2013.[2,12] FAST examinations were routinely performed by senior emergency residents who had completed the hands-on FAST training at our institution. In February 2012, whole-body trauma CT scans, including the neck, chest, abdomen, and pelvis, were introduced at our institution. Since then, whole-body trauma CT was performed before the surgery or intervention during the time required to prepare an operating room without delay of surgery. A 128-channel multidetector CT scanner (Somatom Definition AS Plus; Siemens Medical Solutions, Cary, NC) is only available for use with patients in the ED, and the time required for the CT scan was under 180 seconds. The decision to perform exploratory laparotomy or embolization was made by the trauma surgeon on duty.

Consecutive adult patients (age ≥18 years) with severe blunt trauma who were admitted to our ED between February 2012 and October 2016 were identified from our Trauma Registry. From this population, we included patients with documented hemoperitoneum on whole-body trauma CT. Patients were excluded if they presented to the ED with out-of-hospital arrest, they did not undergo CT before exploratory laparotomy or embolization, or they expired in the ED within 30 minutes of admission. The study patients were assigned to 2 groups based on their vital signs. Hemodynamically unstable patients were defined as those with persistent hypotension (systolic blood pressure <90 mm Hg or mean blood pressure <65 mm Hg) despite over a 30 mL/kg fluid bolus.

2.2. Measures

Demographic and clinical data, including age, sex, injury mechanism, vital signs, laboratory values, CT findings, and intraoperative findings were collected from the electronic medical records. The findings of whole-body trauma CT scans with intravenous contrast or exploratory laparotomy were used as confirmatory findings for organ injury. The severity of the injury was assessed by the Injury Severity Score (ISS) and Revised Trauma Score (RTS).[13,14] The timing of the CT scan after ED presentation and the duration of ED stay were also calculated. The total amount of transfusion within 24 hours of ED presentation, the management during hospitalization, and outcome were also recorded.

2.3. Data analysis

Continuous variables are expressed as medians with interquartile range (IQR) due to the lack of normal distribution, whereas categorical variables are presented as numbers and percentages. The Mann–Whitney *U* test was used to compare continuous variables, whereas the Chi-squared or Fisher exact test was applied for categorical variables. Clinical variables of potential predictors of in-hospital mortality were first evaluated using univariate logistic analysis with $< .05$ *P* value cutoff. The significant variables were candidates for the multivariable model and were examined using multiple logistic regression analysis. The results of the multivariate logistic regression analyses were presented as odds ratio (OR) and 95% confidence interval (95% CI). The Hosmer–Lemeshow test for logistic regression model was performed. A 2-sided *P* value of $< .05$ was considered to be statistically significant. All statistical analyses were performed by using SPSS for Windows version 21.0 (SPSS Inc., Chicago, IL).

3. Results

Between February 2012 and October 2016, 147 exhibited hemoperitoneum on CT among 1723 severe blunt trauma patients. After excluding 11 patients, including 6 who presented to the ED with cardiac arrest, 3 who underwent exploratory laparotomy without CT scan, and 2 who expired within 30 minutes of ED arrival, we finally enrolled 136 patients with a median age of 50 years. A total of 29 patients (21.3%) were found to be hemodynamically unstable despite fluid resuscitation.

The demographic and clinical characteristics of the hemodynamically stable and unstable patients are presented in Table 1. The vital signs were significantly different between the 2 groups. Hemodynamically unstable patients showed significantly higher ISS (24.0 vs 35.0, $P<.001$) and lower RTS (7.841 vs 6.376, $P<.001$). The lactic acid (3.0 vs 5.2 mmol/L, $P<.001$) and base excess (−2.6 vs −9.9 mmol/L, $P<.001$) levels were significantly worse in hemodynamically unstable patients. There was no difference in the percentage of intraperitoneal organ injury between the hemodynamically stable and unstable groups (69.2% vs 82.8%, $P=.15$), although the rate of documented active internal bleeding was more than 2-fold that in hemodynamically unstable patients (29.9% vs 69.0%, $P<.001$). Hemodynamically unstable patients also received a greater amount of all types of blood transfusions within the first 24 hours. In the unstable group, only 14 (48.3%) patients underwent emergent operation, 3 (10.3%) patients underwent embolization, and the remaining were treated conservatively.

The injury sites in our study patients are summarized in Table 2. A total of 98 patients with hemoperitoneum (72.1%) developed intraperitoneal injury, and the liver (n=59, 60.2%) was the most frequently damaged site, followed by the spleen (n=23, 23.5%), mesentery (n=23, 23.5%), and bowel (n=17, 17.3%). Approximately half of the hemodynamically unstable patients with intraperitoneal organ injury had coincident thoracic (n=11, 45.8%) and retroperitoneal injury (n=13, 54.2%). Most of the patients without intraperitoneal injury had retroperitoneal injury (n=36, 94.7%).

The majority of the hemodynamically unstable patients were admitted to the intensive care unit (n=19, 65.5%) or were moved directly to the operation room (n=7, 24.1%) (Table 3). Three patients developed cardiac arrest during their ED stay and achieved return of spontaneous circulation following advanced cardiac life support. One patient exhibited massive hemome-

Table 1

Demographic data and clinical findings for the study patients.

	Total (n=136)	Stable (n=107)	Unstable (n=29)	P
Age, y	50.0 (35.8–61.0)	47.0 (32.0–61.0)	55.0 (47.0–61.0)	.14
Male	94 (69.1)	70 (65.4)	24 (82.8)	.07
Injury mechanism				.28
MVC	92 (67.6)	73 (68.2)	19 (65.5)	
Falls	32 (23.5)	26 (24.3)	6 (20.7)	
Assault	3 (2.2)	3 (2.8)	0 (0)	
Others	9 (6.6)	5 (4.7)	4 (13.8)	
Vital signs at ED presentation				
Systolic BP, mm Hg	116.5 (100.0–133.8)	119.0 (104.0–136.0)	85.0 (70.0–110.0)	<.001
Diastolic BP, mm Hg	73.5 (60.0–86.8)	75.0 (64.0–88.0)	51.0 (40.0–73.5)	<.001
Heart rate	92.0 (78.0–106.8)	90.0 (76.0–104.0)	104.0 (81.0–120.5)	.02
Respiratory rate	20.0 (20.0–22.0)	20.0 (20.0–21.0)	22.0 (20.0–26.5)	.002
Injury Severity Score	26.0 (18.0–35.0)	24.0 (17.0–34.0)	35.0 (23.5–50.0)	.002
Revised Trauma Score	7.841 (6.376–7.841)	7.841 (7.108–7.841)	6.376 (2.628–7.108)	<.001
Laboratory test				
Lactic acid levels*, mmol/L	3.6 (2.5–5.2)	3.0 (2.0–4.5)	5.2 (4.2–7.9)	<.001
Base excess levels*, mmEq/L	−3.6 (−8.5 to −1.2)	−2.6 (−6.3 to −0.8)	−9.9 (−12.3 to −4.7)	<.001
Minutes from ED presentation to CT work-up	49.5 (30.0–82.0)	52.0 (30.0–93.0)	38.0 (29.5–53.5)	.051
Intraperitoneal organ injury	98 (72.1)	74 (69.2)	24 (82.8)	.15
Documented active bleeding	52 (38.2)	32 (29.9)	20 (69.0)	<.001
Transfusion within 24 h				
pRBC	2.0 (0.0–8.0)	1.0 (0.0–5.0)	18.0 (7.0–41.5)	<.001
FFP	0.0 (0.0–5.0)	0.0 (0.0–2.0)	8.0 (2.5–35.5)	<.001
PC	0.0 (0.0–0.0)	0.0 (0.0–0.0)	5.0 (0.0–21.0)	<.001
Treatment				<.001
Conservative treatment	71 (52.2%)	61 (57.0)	10 (34.5)	
Emergent laparotomy	29 (21.3)	15 (14.0)	14 (48.3)	
Embolization	7 (5.1)	4 (3.7)	3 (10.3)	
Transfer	29 (21.3)	27 (25.2)	2 (6.9)	

Values are expressed as median with interquartile range and n (%).

BP = blood pressure, CT = computed tomography, ED = emergency department, FFP = fresh frozen plasma, MVC = motor vehicle crash, PC = platelet concentrate, pRBC = packed red blood cells, SpO_2 = oxygen saturation.

* Twenty-six patients in the stable group did not undergo this measurement.

diastinum along with suspected pericardial and great vessel injury, which appeared to primarily contribute to the cardiac arrest, and was transferred directly to the operation room. Another patient had pelvic bone fracture with an actively bleeding iliac artery injury and suspected injury of the inferior vena cava, and underwent emergent embolization. The other patient not only exhibited active extravasation from the spleen but also had severe brain hemorrhage.

In univariate analysis, hemodynamically instability despite fluid resuscitation, ISS, RTS, and respiratory rate showed significant association with in-hospital mortality (Table 4). Among those clinical factors, hemodynamically instability (OR, 7.13; 95% CI, 1.61–31.50) and ISS (OR, 1.11; 95% CI, 1.05–1.17) were independent risk factors for in-hospital mortality.

4. Discussion

In our present study, we found that the rate of intraperitoneal organ injury was not greater in hemodynamically unstable patients with hemoperitoneum (82.8%) than hemodynamically stable patients with hemoperitoneum (69.2%, $P=.15$), and > 25% of patients, regardless of hemodynamic stability, were found to have thoracic or retroperitoneal injuries as the bleeding source of the hemoperitoneum. Even in hemodynamically unstable hemoperitoneum patients, 17.2% had no documented intraperitoneal injury and > 50% were treated without emergent surgery.

The prompt and accurate diagnosis of intraabdominal injury is crucial for the treatment of patients with severe blunt trauma. Although the current guidelines recommend the use of hemoperitoneum on FAST examination as a marker of intraperitoneal injury in hemodynamically unstable patients, this protocol may lead to misdiagnosis and the adoption of an inappropriate hemostatic strategy.[5,15,16] Charbit et al[6] examined the injuries in hypotensive blunt patients with hemoperitoneum on FAST, 90% of whom underwent CT instead of direct exploratory laparotomy, and found that the active bleeding source was of extraperitoneal origin, including the thoracic, retroperitoneal, and pelvic region, in 59% of the patients with active bleeding. Consistent with this previous study, our present findings indicated that 17% of hemodynamically unstable patients did not have intraperitoneal injury, and the remaining 83% of cases with intraperitoneal injury also had thoracic (45.8%) and retroperitoneal (54.2%) injuries.

Deaths after trauma are commonly categorized into immediate, early, and late deaths, based on the timing; for early and late deaths, exsanguination was one of the most common causes of death and accounted for 30% to 40% of cases.[17,18] In our present study, 31.0% of hemodynamically unstable patients (n=9) died during hospitalization, and 55.6% of these patients (n=5) died within 24 hours of ED arrival. Of 5 patients with early death, 3 died due to uncontrolled exsanguination with trauma-related coagulopathy despite the use of hemostatic procedures, and 2 did

Table 2

Injury sites among the study patients.

	Total (n=136)	Stable (n=107)	Unstable (n=29)
With intraperitoneal organ injury	98 (72.1)	74 (69.2)	24 (82.8)
Intraperitoneal organ injury			
Liver	59	44	15
Spleen	23	17	6
Bowel	17	12	5
Mesentery	23	13	10
Abdominal aorta	1	0	1
Others	6	3	3
Thoracic injury	46 (46.9)	35 (47.3)	11 (45.8)
Lung	41	31	10
Heart and great vessels	4	3	1
Intercostal artery	3	2	1
Others	3	3	0
Retroperitoneal injury	34 (34.7)	21 (28.4)	13 (54.2)
Kidney	16	8	8
Adrenal gland	11	8	3
Pelvic vessel	9	3	6
Pancreas	7	3	4
Retroperitoneal hematoma	3	3	0
Without intraperitoneal organ injury	38 (27.9)	33 (30.8)	5 (17.2)
Thoracic injury	13 (34.2)	10 (30.3)	3 (60.0)
Lung	12	9	3
Heart and great vessels	4	3	1
Intercostal artery	1	0	1
Others	2	2	0
Retroperitoneal injury	36 (94.7)	32 (97.0)	4 (80.0)
Kidney	10	10	0
Adrenal gland	2	2	0
Pelvic vessel	16	13	3
Pancreas	0	0	0
Retroperitoneal hematoma	12	11	1

Values are expressed as n (%).

Table 4

Univariate and multivariate analysis of in-hospital death in the study patients.

	Univariate analysis			Multivariate analysis		
	OR	95% CI	*P*	OR	95% CI	*P*
Age	1.01	0.98–1.05	.51			
Female	1.45	0.45–4.74	.53			
Hemodynamically instability	11.59	3.25–41.32	<.001	7.13	1.61–31.50	.01
ISS	1.12	1.07–1.19	<.001	1.11	1.05–1.17	<.001
RTS	0.53	0.39–0.71	<.001			
Heart rate	1.02	0.99–1.05	.18			
Respiratory rate	1.17	1.05–1.30	.004			

CI = confidence interval, ISS = Injury Severity Score, OR = odds ratio, RTS = Revised Trauma Score.

not undergo procedures due to brain death. These findings were consistent with those of a previous study series in which one-third of the hemodynamically unstable patients died during hospitalization, the majority within 24 hours.[6]

Among the hemodynamically unstable patients in our current study population, 10 (34.5%) were treated conservatively and 8 of those 10 patients (80.0%) recovered without any interventions. Recent studies have indicated that the selective nonoperative management of blunt hepatic and splenic injuries is a feasible strategy, even for hemodynamically unstable patients or those with a high grade of injuries.[19,20] Our present findings are consistent with these previous results, which implies that selectively performing CT scans would help physicians reduce unnecessary laparotomy in hemodynamically unstable patients.

In blunt trauma patients, the spleen and liver are the 2 most commonly injured abdominal organs.[21] We observed this in the present study as well, regardless of hemodynamic stability. In addition to the injuries of the liver (n=59, 43.4%) and spleen (n=23, 16.9%), thoracic injury (n=59, 43.4%) was also frequently observed in our study patients. Hence, in severe blunt trauma patients, physicians should consider the possibility of simultaneous injuries in both the thoracic and peritoneal regions.[6] Even in hemoperitoneum patients, hemodynamic instability could be the cause of a lethal injury in the thoracic region. In the present study, 1 of 4 patients with injuries of the heart and great vessels died due to massive hemopericardium, despite the use of emergent thoracotomy. CT scans may have a role in detecting and managing such patients appropriately.

The main limitation of our present study was its descriptive study design. We could not investigate the impact of CT scan on patient outcomes because almost all severe blunt trauma patients at our institution underwent whole-body trauma CT scan in the ED during the study period. Moreover, our study was conducted at a single institution, which limits the generalization of our findings. Furthermore, the small sample size and selection bias due to our retrospective design may have influenced the results.

In summary, we found that even among hemodynamically unstable patients with hemoperitoneum, 17.2% had no documented intraperitoneal injury, and over 50% were treated without an emergent operation. Direct exploratory laparotomy was not always mandatory for hemodynamically unstable hemoperitoneum patients, as this procedure could delay appropriate treatment and yield fatal outcomes on occasion. Although further studies are needed to clarify the appropriate strategy for hemodynamically unstable patients with blunt trauma, the use of selective CT scan before explore laparotomy might help clinicians obtain critical information.

Table 3

Study patient outcomes.

	Total (n=136)	Stable (n=107)	Unstable (n=29)	*P*
ED disposition				.002
ICU admission	67 (49.3)	48 (44.9)	19 (65.5)	
GW admission	24 (17.6)	23 (21.5)	1 (3.4)	
Operating room	16 (11.3)	9 (8.4)	7 (24.1)	
Transfer	29 (21.3)	27 (25.2)	2 (6.9)	
ED stay duration, min	252 (155–410)	277 (187–441)	169 (87–252)	<.001
Death <24 h	5 (3.7)	0 (0)	5 (17.2)	<.001
In-hospital death	13 (9.6)	4 (3.7)	9 (31.0)	<.001
Conservative treatment	4	1	2	
Emergent laparotomy	7	3	5	
Embolization	2	0	2	

Values are expressed as median with interquartile range and n (%).
ED = emergency department, ICU = intensive care unit, GW = general ward.

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