Journal of Trauma & Treatment

Hsu, et al., J Trauma Treat 2016, 5:3
DOI: 10.4172/2167-1222.1000316

Research Article Open Access

Isolated Free Fluid without Pneumoperitoneum on Computed Tomography in Blunt Abdominal Trauma: Laparotomy Better Based on Imaging Finding and Clinical Presentation

Yu-Pao Hsu*, Chien-Hung Liao, Kuo-Ching Yuan, Chih-Yuan Fu, Being-Chuan Lin, Shih-Ching Kang and Shang-Yu Wang

Trauma Center, Department of Trauma and Emergency Division, Surgical Department, Chang-Gung Memorial Hospital, Chang-Gung University, Fu-Shing Street, Kweishan, 333, Taoyuan, Taiwan

***Corresponding author:** Yu-Pao Hsu, Trauma Center, Department of Trauma and Emergency Division, Surgical Department, Chang-Gung Memorial Hospital, Chang-Gung University, Fu-Shing Street, Kweishan, 333, Taoyuan, Taiwan, Tel: +88633281200; Fax: +886-3-3289582 E-mail: yupao@cgmh.org.tw

Rec date: Jun 23, 2016; **Acc date:** Jul 08, 2016; **Pub date:** Jul 11, 2016

Abstract

Background: This study examines the clinical assessment and management of patients sustaining blunt abdominal trauma (BAT) with unexplained intra-abdominal free fluid.

Methods: All adult patients (age ≥18 years) presenting with BAT to our trauma center over a 7-year period were reviewed. Those with abdominal computed tomography (CT) demonstrating intra-peritoneal free fluid but neither solid organ injury nor pneumoperitoneum were studied further. Demographic data, radiologic interpretation, operative findings, clinical management and outcome were analyzed.

Results: 115 patients met the inclusion criteria. Except 9 patients for non-operative management, 91 patients (86%) underwent therapeutic laparotomy, in whom 83 patients (78%) benefited from surgical intervention and 15 patients (14%) underwent non-therapeutic laparotomy, in whom 8 patients (8/15=53%) had retroperitoneal hematoma with associated pelvic fractures. Mesenteric tear, urinary bladder rupture, and bowel injury constituted 81% (93/115) of the studied patients. Both bowel injury and mesenteric tear had a significantly higher rate of bowel wall thickening, mesenteric hematoma and streaky sign on CT scan. Urinary bladder rupture was associated with a significantly longer hospital stay, higher injury severity score (ISS), a higher rate of associated pelvic fracture (47%) and gross hematuria (97%).

Conclusions: Laparotomy might be suggested for BAT patients with free fluid collection without solid organ injury and pneumoperitoneum on CT scan because most of these patients benefited from the surgical intervention (78%), especially when there are combined with clinical presentation of gross hematuria or CT images of bowel wall thickening or mesenteric lesion.

Keywords: Intra-abdominal free fluid; Solid organ injury; Non-operative management; Bowel injury; Mesenteric tear; Urinary bladder rupture

Introduction

Non-operative management for blunt abdominal trauma (BAT) is considered the treatment of choice for patients with stable hemodynamic status [1,2]. Due to the high efficiency and accuracy of abdominal computed tomography (CT) in the identification of solid organ injury, it is increasingly utilized for stable patients sustaining BAT [3,4]. However, the diagnosis of hollow viscus or diaphragmatic injury remains difficult. The diagnostic signs of bowel perforation are oral contrast extravasation and pneumoperitoneum; however, both diagnostic signs in the case of bowel injury have high specificity, but low sensitivity [5-7]. Other suggested signs of bowel injury, including bowel wall thickening, streaking of the mesentery, dilated bowel loops, and free fluid without solid organ injury, were unreliable [7-9].

In cases of peritoneal fluid collection with solid organ injury on CT scan, a non-operative management strategy is widely accepted. When free air is identified in the peritoneum or extravasation of oral contrast is seen, laparotomy is justified for suspected bowel injury. However, a diagnostic dilemma arises, when free fluid is identified without solid organ injury or pneumoperitoneum. The optimal management of these patients remains controversial [10-12].

The purpose of this study was to determine the clinical assessment and management of adult BAT patients with CT evidence of intra-peritoneal free fluid, but without either solid organ injury or pneumoperitoneum.

Patients and Methods

A retrospective study of patients who presented with BAT to our hospital (a trauma center in northern Taiwan) was undertaken. All patients who presented to the emergency department (ED) with suspected BAT during a 7-year period from July 2008 to June 2015 were eligible for inclusion and were studied using a management protocol to determine the severity of abdominal trauma. Focused assessment of sonography for trauma patients (FAST) was performed on all patients by surgical residents or trauma attending doctors using a portable ultrasound scanner and a 3.75 MHz curvilinear probe (SonoSite CRT Stand REF:P02882-02, Bothell, WA, USA) during or

after completion of the primary survey. The presence or absence of free fluid and the location of any fluid was recorded. Unstable patients with a positive FAST scan were taken to the operating room for laparotomy. Stable patients with positive or undetermined sonograms underwent CT scanning.

CT scans were obtained on a GE-Light Speed Advantage scanner (General Electric Medical Systems, Milwaukee, WI). No oral contrast was administered before imaging. Either 320 mg/mL (Optiray 320, Mallinckrodt Medical, Point-Claire, Quebec, Canada) or 282 mg/mL (Conray 60, Mallinckrodt Medical) of intravenous (IV) contrast containing Iodine, was given by rapid bolus injection at a rate of 2.5-3.0 ml/s using power injection. Helical scanning was performed from the dome of the diaphragm to the symphysis pubis with a 10 mm slice thickness, 5 mm reconstruction, and 1:1 pitch.

The radiology and trauma resident or attending staff interpreted the CT scans during normal hours. At other times, interpretation was made by the on-call radiology resident or attending staff with the trauma resident or surgeon. All clinical management decisions were made after the initial radiology interpretation. Emergent laparotomy was performed, if the CT scan demonstrated intra-peritoneal free air. Diagnostic peritoneal lavage (DPL) was performed to detect a possible hollow organ perforation, if diffuse abdominal pain was present or if CT scan demonstrated the suggested signs of bowel injury (bowel wall thickening, mesenteric streaky sign or hematoma). The decision to proceed with laparotomy was made at the discretion of the attending trauma surgeon based upon Fang's criteria for DPL data and the radiology findings [13]. For patients with an altered level of consciousness (LOC) (motor exam ≤5 of Glasgow coma scale, GCS) and CT scan with suggestion of bowel injury, DPL was performed to determine if laparotomy was required. Retrograde cystogram was performed in case of BAT with gross hematuria, especially concomitant with pelvic fracture. The laparotomy was defined as therapeutic, if an injury was identified to explain the presence of the fluid and the measures were taken to correct the underlying problem. The benefit laparotomy was defined as that trauma patients really benefited from the surgery. Patients with a non-operative management course were admitted for observation, and associated injuries were treated according to the usual standard of care. Successful observation was defined as a patient who did not require laparotomy during the hospital admission and did not represent to the hospital within 30 days of discharge with an abdominal complication.

Patients who exhibited CT scan evidence of either solid organ injury or pneumoperitoneum were excluded from the study. Those patients with free intra-peritoneal fluid and neither pneumoperitoneum nor identifiable solid organ injury constituted the study group.

The CT scans of patients in the study group were reviewed by two abdominal radiologists. They were blinded to the operative findings (extent of injuries, presence of pneumoperitoneum, bowel wall thickening, mesenteric streaky signs, mesenteric hematoma, and presence/location of intra-peritoneal fluid) in patients who underwent laparotomy. The following spaces were evaluated for free fluid: perisplenic, perihepatic, Morrison's pouch, left and right paracolic gutters, and pelvis. Peritoneal fluid collections were then graded according to the method described by Federle and Jeffrey [14]. Small collections were defined as fluid in one space. Moderate collections were defined as fluid in two or more spaces. Large collections were defined as fluid in all spaces.

In this study, the inclusion criteria were trauma patients who were ≥18 years of age, had sustained BAT, and had intra-peritoneal fluid collections on CT scans. The exclusion criteria were trauma patients less than 18 years of age, and those who had sustained penetrating abdominal injury, associated with either solid organ injury, or intra-peritoneal free air.

The following demographic data was also recorded: age, gender, hemodynamic status on arrival in the ED, need for blood transfusion in the ED, LOC in the ED, CT scan results, DPL data, presence of pelvic fracture, presence of gross hematuria, need for cystography, laparotomy (therapeutic or non-therapeutic), final definitive diagnosis, injury severity score (ISS), new injury severity score (NISS), complications, and outcome. Data is expressed as mean ± standard deviation (X±SD). A chi-square test was used to investigate the categorical variants in data among patients, and statistical analyses were performed using Tukey's HSD Test for numerical variants in data. The level of statistical significance was $p<0.05$.

Results

Between July 2008 to June 2015, 2,235 patients sustained BAT and were retrospectively reviewed. FAST scans were positive or indeterminate for free fluid in 731 patients. Ninety two of these patients were hemodynamically unstable and were taken to surgery; they did not undergo further diagnostic imaging. The remaining 639 stable patients underwent abdominal CT scanning. Of these, 487 patients exhibited radiologic evidence of solid organ injury and were excluded from the study. Among the remaining 152 patients with free peritoneal fluid collections and no solid organ injury visible on CT imaging, 27 patients had identifiable intra-peritoneal free air and were also excluded from the study. Ten patients were under the age of 18. The remaining 115 patients comprised the study group. A flow diaphragm displaying total number of patients was shown as (Figure 1).

The median age of the 115 patients was 39.8 ± 14.5 years (range 18-77). Median blood transfusion in ED was 1.6 ± 2.3 units (range 0-4). The median ISS was 17.8 ± 12.6 (range 4-50). The median NISS was 19.1 ± 13.7 (range 4-57). Other demographic data were shown in Table 1. There were 92 male's patients and 23 female patients. The mechanism of injury was motor vehicle crash in 37 patients, motorbike crash accident in 44 patients, pedestrian in 11 patients, falls in 12 patients, assault in 5 patients, and weight compression in 6 patients. On arrival on ED, there were 30 patients with hypotension, but all were successfully resuscitated.

The CT scan results identified the majority of the intra-peritoneal fluid collections as moderate to large (91/115). CT imaging also revealed 28 patients (24%) had intestinal wall-thickening. 19 patients (25%) had mesenteric hematoma. 54 patients (47%) had mesenteric streaky sign; and 8 patients had contrast extravasation due to active hemorrhage. Using Fang's criteria, DPL was performed in 39 of the 115 patients. Twelve of those patients had positive findings, in whom 9 patients demonstrated bowel perforation, 2 patients demonstrated mesenteric tear, and the remaining 1 patients revealed negative findings on laparotomy. Among the 115 studied patients, fourteen exhibited altered LOC (motor exam ≤5 of GCS). Nine of those patients had intracranial hemorrhages (epidural hematoma, subdural hematoma, or subarachnoid hemorrhage). Retrograde cystography was performed in twenty eight patients (25%) with gross hematuria and/or

pelvic fracture. Twenty of those patients had evidence of intra-peritoneal rupture.

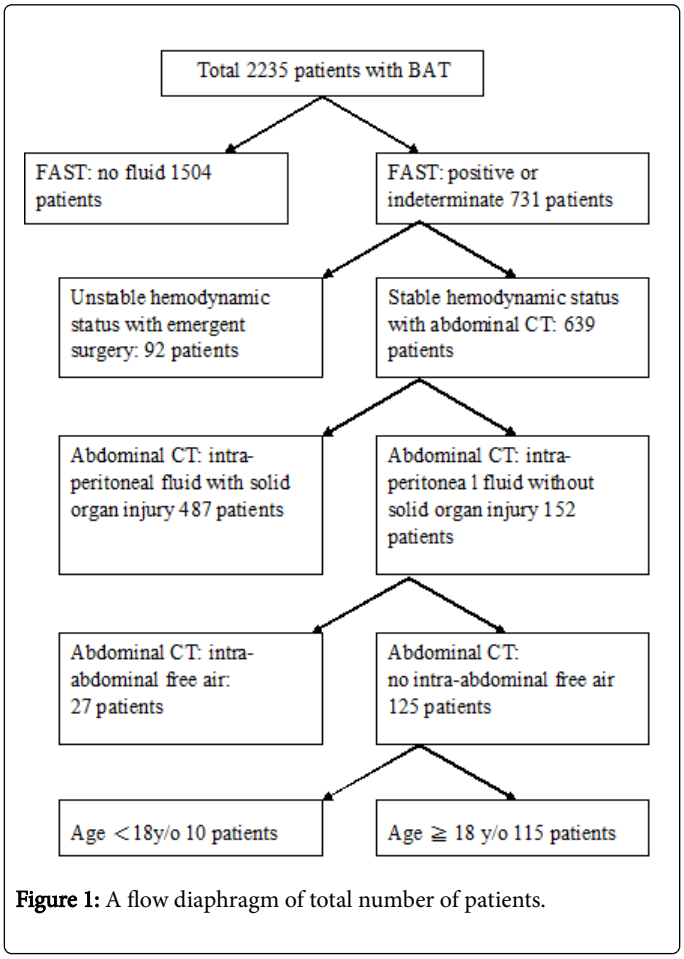

Figure 1: A flow diaphragm of total number of patients.

Of the 115 patients studied, the vast majority underwent surgical intervention (106/115). The other nine patients were managed non-operatively. In the surgical group, 2 patients received laparoscopic examination with only evacuation of peritoneal blood; 13 patients underwent non-therapeutic laparotomy. Among these fifteen patients (laparoscopic surgery plus non-therapeutic laparotomy), ten patients (67%) developed retroperitoneal hematoma-related hemoperitoneum, in whom 8 patients had concomitant pelvic fracture. The remaining 5 patients demonstrated only minor mesenteric tears. Ninety one patients underwent therapeutic laparotomy according to the definition of surgical tissue repair; among them, there were 32 patients sustaining urinary bladder rupture with 29 patients with intra-peritoneal rupture and 3 ones with extra-peritoneal rupture, 47 patients sustaining mesenteric tear with 38 patients with significant tear (≥3.0 cm laceration in length), in whom 8 patients had hypovolemic shock during the pre-operative course despite initial response to the resuscitation and 3 patients finally expired due to massive hemorrhage, 14 patients sustaining bowel perforation with 2 patients combined with mesenteric tear, and 2 patients sustaining gallbladder rupture. In terms of therapeutic laparotomy with tissue repair, the rate was 91/106 (86%); if I collected the patients sustaining intra-peritoneal rupture of urinary bladder (29 patients), significant mesenteric tear (38 patients), bowel perforation (14 patients) and gallbladder rupture (2 patients) as the patients really benefiting from the surgical intervention, the rate of "benefit laparotomy" was 83/106 (78%). Post-operative complications occurred in 14 patients and were mostly related to wound infection. There were 6 patients with mesenteric tear undergoing emergent laparotomy due to subsequent hemodynamic change and 3 fatalities secondary to mesenteric tears associated with massive intra-peritoneal hemorrhage, hypovolemic shock, and multiple organ system dysfunction.

Item		No (%)
Sex	Male	92 (80)
	Female	23 (20)
Trauma mechanism	MVC	37 (32)
	MBC	44 (38)
	Pedestrian struck	11 (10)
	Fall	12 (10)
	Assault	5 (4)
	WC	6(5)
Shock on arrival	(+)	85 (74)
		30 (26)
CT Image Hemoperitoneum	Small	24 (21)
	Moderate	49 (43)
	Large	42 (36)
Wall thickening	(-)	87 (76)
	(+)	28 (24)
Mesenteric hematoma	(-)	86 (75)
	(+)	29 (25)
Streaky sign	(+)	61 (53)
		54 (47)
Contrast extravasation	(+)	107 (93)
		8 (7)
Head injury with coma (M ≤ 5)	(-)	101 (88)
	(+)	14 (12)
	Non-ICH	5(4)
	ICH	9(8)
DPL	None	76 (67)
	Positive finding	12 (10)
	Negative finding	27 (23)
Surgery	None	9 (8)
	Therapeutic	91 (79)
	Non-therapeutic	15 (13)
Complication	(-)	101 (88)
	(+)	14 (12)

Death	(-)	112 (97)
	(+)	3 (3)

DPL: Diagnostic peritoneal lavage. ICH: Intracranial hemorrhage. MBC: Motorbike crash. MVC: Motor vehicle crash. WC: Weight Compression

Table 1: The demographic data of total 115 patients.

The diagnoses for the BAT in the study patients is shown in Table 2. Among the patients undergoing laparotomy, mesenteric tears (n=47), bladder rupture (n=32), intestinal perforation (n=12), and combined mesenteric tear and bowel perforation (n=2), constituted 81% (93/115) of the study group. The remaining patients included 10 cases of retroperitoneal hematoma, 2 cases of gallbladder rupture, and one case of ruptured ovarian cyst. Nine cases did not require surgical intervention. In 32 urinary bladder rupture patients, 15 patients (47%) have associated pelvic fractures and 31 patients (97%) have gross hematuria.

Diagnosis	Number (%)
Urinary bladder rupture	32 (27.8)
Mesenteric tear	47 (40.9)
Bowel perforation	12 (10.4)
Combined bowel and mesenteric injury	2 (1.7)
Retroperitoneal hematoma	10 (8.7)
Gall bladder rupture	2 (1.7)
Ovarian cyst rupture	1 (0.9)
Non-operative management	9 (7.8)
Total	115 (100.0)

Table 2: The definitive diagnosis of total 115 patients.

From among the 93 patients who underwent laparotomy, three groups of patients were characterized: Group A-32 patients with isolated bladder rupture; Group B-47 patients with isolated mesenteric tear; and Group C-12 patients with isolated intestinal perforation. The two patients with both mesenteric tear and bowel perforation were excluded. Table 3 shows Group B (mesenteric tear) had a significantly higher rate of large peritoneal fluid collection compared to Group A (bladder rupture) and a lower rate of small peritoneal fluid collection compared to Group C (intestinal perforation).

Item	Group (No)	A (32)	B (47)	C (12)	Total
Trauma Mechanism	MVC	9 (29%)	17 (36%)	4 (33%)	30
	MBC	15 (47%)	16 (34%)	6 (50%)	37
	Pedestrian struck	2 (6%)	7 (15%)	1 (8%)	10
	Fall	3 (9%)	5 (11%)	0	8
	Assault	2 (6%)	0	1 (8%)	3
	WC	1 (3%)	2 (4%)	0	3
Sex	Male	27 (84%)	40 (85%)	10 (83%)	77
	Female	5 (16%)	7 (15%)	2 (17%)	14
Shock on arrival	(-)	26 (81%)	32 (68%)	8 (67%)	66
	(+)	6 (19%)	15 (32%)	4 (33%)	25
CT image: peritoneal fluid	Small	8 (25%)	6 (13%)	6# (50%)	20
	Moterate	16 (50%)	16 (34%)	2 (17%)	34
	Large	8 (25%)	25* (53%)	4 (33%)	37
Walling thickening	(-)	30 (94%)	30 (64%)	4 (33%)	64
	(+)	2 (6%)	17* (36%)	8* (67%)	27
Mesenteric hematoma	(-)	31 (97%)	24 (51%)	8 (67%)	63
	(+)	1 (3%)	23* (49%)	4* (33%)	28
Mesenteric streaky sign	(-)	29 (91%)	9 (19%)	2 (17%)	40
	(+)	3 (9%)	38* (81%)	10* (83%)	51
Contrast extravasation	(-)	31 (97%)	41 (87%)	11 (92%)	83
	(+)	1 (3%)	6 (13%)	1 (8%)	8
DPL	None	22 (69%)	39 (83%)	6 (50%)	65
	Positive finding	0	2 (4%)	5*# (42%)	7
	Negative finding	10 (31%)	6 (13%)	1 (8%)	17
Intracranial hemorrhage	(+)	5(16%)	1(2%)	3(25%)	9
Complication	(-)	30 (94%)	41 (87%)	8 (67%)	79
	(+)	2 (6%)	6 (13%)	4* (33%)	12
Death	(-)	32 (100%)	45 (96%)	12 (100%)	89
	(+)	0	2*# (4%)	0	2

Group A: Urinary bladder rupture. Group B: Mesenteric tear. Group C: Intestinal perforation. *: P<0.05, compared to group A.#: P<0.05, compared to group B. Using Chi-square statistical analysis. DPL: Diagnostic peritoneal lavage. MBC: Motorbike crash. MVC: Motor vehicle crash. WC: Weight Compression.

Table 3: The categorical data in group A (urinary bladder rupture), group B (mesenteric tear), and group C (intestinal perforation).

Group B (mesenteric tear) and Group C (intestinal perforation) both had a significantly higher rate of bowel wall-thickening, mesenteric hematoma, and mesenteric streaky sign, compared to Group A (bladder rupture). Group C (intestinal perforation) had a significantly higher rate of positive DPL compared to Group A (bladder rupture) or Group B (mesenteric tear), as well as a significantly higher rate of post-operative complication. Group B (mesenteric tear) had the highest post-operative mortality rate.

Table 4 revealed some trends in the patient data among the three groups. Group A (bladder rupture) constituted a significantly older population than Group C (intestinal perforation). Group A also exhibited significantly higher rates of hospital stay, ISS, and NISS compared to Groups B (mesenteric tear) and C (intestinal perforation).

Group (N) / Item	A (32)	B (47)	C (12)

Age (y/o)	34.4 ± 11.6*	42.1 ± 14.4	48.3 ± 14.3
BT (unit)	2.0 ± 2.5	1.4 ± 2.3	1.7 ± 2.0
HS (day)	22.9 ± 21.1#	17.4 ± 15.8	18.3 ± 16.6
ISS	27.4 ± 10.5#	11.4 ± 8.7	15.9 ± 8.8
NISS	29.5 ± 11.5#	12.7 ± 9.5	16.8 ± 8.8

BT: Blood transfusion. HS: Hospital stay. ISS: Injury Severity Score. NISS: New Injury Severity Score. * Compared to Gr C, p=0.025. # Compared to Gr B and C, HS: p=0.037, ISS: p=0.022, NISS: p=0.039. *, # Mean p<0.05, using Tukey HSD statistical analysis. Fluid: intra-operative measurement of peritoneal fluid volume in patients of no DPL performed.

Table 4: The numerical data in Group A (urinary bladder rupture), Group B (mesenteric tear), and Group C (intestinal perforation).

Peritoneal Fluid: N (%)				
	Small	**Moderate**	**Large**	**Total**
Therapeutic operation	18 (86)	36 (82)	37 (90)	91
Non-therapeutic operation	3 (14)	8 (18)	4 (10)	15
No statistical significance using *Chi-square* test				

Table 5: The CT-image peritoneal fluid amount in therapeutic and non-therapeutic operative patients.

Discussion

FAST, CT scanning, and /or DPL are used to determine the presence and severity of injuries in trauma patients sustaining BAT [3,4,14,15]. FAST has recently gained popularity in the rapid assessment of patients, but it is not designed to be organ-specific. With the technological advances in helical scanning (multitrack scanners and improved resolution), the CT scan has become the standard of care for assessing injuries in hemodynamically stable patients sustaining BAT. However, the CT scan has a weakness in the diagnosis of blunt bowel injury. False negative interpretations can vary widely from 10%-80% in patients sustaining hollow viscus injuries [2,6,7,9,16].

When considering non-operative management of trauma patients, judgments regarding the significance of peritoneal free fluid without solid organ injury are critical. Both intra-peritoneal free air and extravasation of oral contrast are diagnostic signs of bowel injury on CT scan, and exploratory laparotomy is justified. Patients who met these criteria were excluded from the study. In the ED, no oral contrast was administered; therefore, the presence of intra-peritoneal free air was the only diagnostic sign for justified laparotomy. In our algorithm of management of patients sustaining BAT, CT scan was the primary tool for the identification of bowel injury. In cases of CT suggested bowel injury (isolated peritoneal free fluid, bowel wall-thickening, mesenteric streaky sign, mesenteric hematoma), DPL is recommended. Any intra-peritoneal fluid is then examined with respect to its gross appearance, cell count ratio, gram stain, and amylase level, as recommended by Fang et al. [13]. The sensitivity of the CT scan's diagnostic and suggested signs was 40% and 49% respectively; however, the cell count ratio sensitivity was high to 98%.

Laparotomy is still controversial for BAT patients with peritoneal free fluid without solid organ injury. In the thorough literature search done by Banz et al. there is no straight forward answer to the question of what to do with victims with intra-peritoneal free fluid on CT scanning but without signs of organ injury, due to lacking the statistical power to provide a definite answer [17]. Survey results of the management strategies for hypothetical BAT patients were published in AAST (American Association of Surgeon of Trauma). 328 members responded with varied management strategies: 42% DPL, 28% observation, 16% laparotomy, and 12% repeat CT scan. [12] Hulka et al. recommended no mandate for immediate laparotomy in pediatric patients, in whom 75% of patients (18/24) were successfully managed with non-operative methods, and 25% of patients (6/24) received laparotomy due to bowel injury [10].

Both Brasel et al. and Ng et al. advocated mandatory laparotomy for patients with more than a trace amount of fluid [18,19]. However, 62% of patients (21/34) in Brasel's series were successfully managed non-operatively, and half of those patients presented with trace amounts of intra-peritoneal fluid on CT scan [18]. 54% (7/13) of patients undergoing laparotomy were therapeutic (4 patients with bowel injury, 2 patients with mesenteric tear, and 1 patient with diaphragmatic rupture). In Ng's series, 75% (21/28) of patients underwent laparotomy. Only 50% (4/8) of patients with small fluid amount were therapeutic laparotomies, while 92% (12/13) of patients with moderate to large fluid amounts were therapeutic [19].

In the series of Drasin et al., 19 BAT patients with free intra-peritoneal fluid and no identifiable injury were all smoothly discharged without surgical intervention. In the report of Venkatesh et al., 31 similar patients with small amount of intra-peritoneal free fluid were successfully managed non-operatively. Both authors suggested that non-operative management of stable patient with small amounts of free fluid in the absence of identifiable injury is appropriate [20,21]. In the large series of patients reported by Conser-Hafertepen et al., 142 victims in total 156 patients (91%) sustaining blunt abdominal trauma having isolated intra-peritoneal free fluid had successful non-operative management, and the remaining 14 patients underwent exploratory laparotomies, with 13 patients proven to be therapeutic. He found that the presence of a moderate to large amount of intra-peritoneal free fluid was increased in the therapeutic operative group with odds ratio 66 [22].

According to Rodriquez et al., the early diagnosis of hollow viscus injury in patients sustaining BAT is difficult, and the immediate laparotomy for all patients with isolated peritoneal free fluid would yield a negative laparotomy rate of 73%. Conversely, observation alone would lead to a delay in diagnosis in the 27% of patients who do have a bowel injury [12].

In our series, therapeutic laparotomy comprised 86% (91/106) of patients undergoing surgery (laparoscopic surgery and laparotomy). Mesenteric tear, bladder rupture, and intestinal perforation comprised 81% of these patients. Rare conditions, such as gallbladder rupture and ovarian cyst rupture, were also noted in our series. 14% (15/106) of patients who underwent surgery were non-therapeutic. The majority of these patients sustained large retroperitoneal hematomas with rupture into the peritoneal cavity (10/15=67%). This is a higher rate than that found in the literature (mesenteric or retroperitoneal hematoma comprised 40-50% of all non-therapeutic laparotomies) [18,19]. The therapeutic laparotomy rate for BAT patients with isolated peritoneal free fluid varied widely from 7.8% to 93.5% [8,10-12,18-20,23-27]. This large variation in the therapeutic laparotomy rate is likely secondary to differences in both the definition of therapeutic laparotomy and the criteria selected for laparotomy by the various authors. However, how

many patients really benefited from the surgical intervention? In my opinion, major mesenteric tear (≥3.0 cm in length), and hollow organ perforation (intra-peritoneal urinary bladder rupture, gallbladder rupture, and bowel perforation) would need and benefit from the surgery. In our series, it accounted for 78% of these patients (83/106).

Eighty percent of the non-therapeutic surgical patients with retroperitoneal hematoma-related hemoperitoneum had concomitant pelvic fracture. Ruchholtz et al. recommended that an unstable pelvic fracture and the presence of intra-abdominal free fluid requires surgical intervention [28]. Friese et al. also demonstrated that 11 of 20 patients with pelvic fractures and intra-peritoneal fluid collections were therapeutic laparotomies [29]. Verbeek et al., suggested that non-therapeutic laparotomy must be avoided in patients with major pelvic fracture due to unacceptably high hemorrhage-related mortality [30].

Patients with BAT can present with LOC, which can decrease the accuracy of the clinical examination. In this situation, significant pathology can be inadvertently overlooked. In our series, DPL was considered based solely on the CT scan findings suggestive of bowel injury for the 14 patients with altered LOC. Five patients underwent DPL, and three were positive. Laparotomy confirmed a bowel perforation in all three cases.

Among the three therapeutic laparotomy groups described previously, the bladder rupture group had the highest ISS and NISS scores. This finding might be partially attributed to the higher Abbreviated Injury Scale (AIS) for bladder rupture (AIS of urinary bladder rupture=4; AIS of intestinal perforation=3) and partially to its frequent association with other serious injuries (48% of bladder rupture associated with pelvic fracture). BAT can result in contusions on mesentery and bowel, thereby creating the characteristic mesenteric and bowel wall changes seen on CT scan (mesenteric neo-vascularization, hematoma, or bowel wall edema) [5-6]. The mesenteric tear and intestinal perforation groups did demonstrate higher rates of bowel wall thickening, mesenteric hematoma, and mesenteric streaky sign on CT scan than the bladder rupture group. The intestinal perforation group had a significantly higher rate of positive DPL findings (as defined by cell count ratio, Gram stain, and amylase levels) than the bladder rupture and mesenteric injury groups. In our series, we clearly proved that DPL and the analysis of intra-peritoneal fluid according to Fang et al. were appropriate techniques to differentiate an intestinal perforation from a mesenteric tear or bladder rupture [13].

Larger peritoneal fluid collections were identified on CT scan in those patients with mesenteric tear (Group B) compared to those patients with bladder rupture (Group A). Patients with intestinal perforation (Group C) were more likely to have smaller fluid collections on CT scan. These findings may be related to the relatively large amount of bleeding from mesenteric laceration. Intestinal perforation generally results in smaller fluid collections from leakage of bowel content; however, Hulka et al. demonstrated 50% of bowel injuries showed moderate amounts of fluid collection. [10]

The CT scan findings of bowel wall edema, mesenteric hematoma, and mesenteric streaky sign occurred more frequently in patients with mesenteric tear (Group B) and intestinal perforation (Group C) than with bladder rupture (Group A). These CT scan findings are reliable indicators for the differentiation of bladder rupture from mesenteric or intestinal injury in cases of isolated peritoneal fluid collection.

Prompt evaluation of BAT patients is crucial in order to expedite surgical intervention for those critical patients. Abdominal CT scanning is not indicated when the patient is hemodynamically unstable or the FAST reveals massive fluid in the peritoneum. The presence of IV contrast extravasation on CT scan is concerning for mesenteric tear and can quickly lead to hypovolemic shock. Emergent laparotomy is critical in these patients. Not surprisingly, patients in this study with mesenteric tear (Group B) had the highest mortality rate from rapid arterial bleeding. Post-operative wound infection occurred most frequently in patients with intestinal perforation (Group C) due to contamination from fecal matter.

In our study, BAT patients with small, moderate, or large amounts of peritoneal fluid collection had a 75%, 73%, and 88% therapeutic laparotomy rate, respectively. This was not a significant difference, which supports the idea that laparotomy should be recommended for all patients with isolated fluid collection, except those patients with retroperitoneal hematoma [11]. However, this recommendation contradicts previous recommendations that stated mandatory laparotomy was only recommended for patients with more than a small fluid collection and not recommended in pediatric BAT patients [10,18,19].

In the large series of 122 relevant patients reported by Mahmood et al., a total 34 patients underwent laparotomies with 31 patients being therapeutic intervention, in whom 23 victims were bowel injuries. He recommended that detection of intra-peritoneal fluid by CT scan is inaccurate for prediction of bowel injury or need for surgery; however, the correlation between scan findings and clinical course is important for optimal diagnosis of bowel injury [31].

The limitations of this study include that it was a retrospective study, a small number of patients in single institution leading to type 2 statistical errors, and the obscure definition of the therapeutic or benefit laparotomy. But, it could provide the useful information regarding the management of this kind of trauma patients.

To sum up, in our series, the rate of therapeutic laparotomy was 91/106 (86%) according to the definition of surgical tissue repair; however, the rate of benefit laparotomy was 83/106 (78%) according to trauma patients really benefiting from the surgical intervention. Minimal invasive laparoscopic exploration may be considered as the good first choice in this setting. Patients with concomitant retroperitoneal hematoma and pelvic fracture are exceptions to this recommendation. Urinary bladder rupture, mesenteric tear, and bowel injury comprised the majority (81%) of findings in patients who underwent therapeutic laparotomy. The latter two injuries had a higher percentage of CT scan findings with bowel edema, mesenteric hematoma, and mesenteric streaky change. Urinary bladder rupture may be considered, if patients have free fluid on CT scan, combined with pelvic fractures (47%) and gross hematuria (97%). Based upon our studies, operation might be suggested for BAT patients with free intra-peritoneal fluid in the absence of pneumoperitoneum on CT scan because most of these patients benefited from the surgical intervention (78%), especially combined with clinical presentation of gross hematuria or CT images of bowel wall thickening or mesenteric lesion.

Acknowledge

The authors thank the members of trauma registration team of Chang Gung Memorial Hospital for their assistance with patient data collection and statistical analysis.

References

1. Pachter HL, Knudson MM, Esrig B, Ross S, Hoyt D, et al. (1996) Status of non-operative management of blunt hepatic injuries in 1995: a multicenter experience with 404 patients. J Trauma 40: 31-38.
2. Croce MA, Fabian TC, Menke PGl, Waddle-Smith L, Minard G, et al. (1995) Non-operative management of blunt hepatic trauma is the treatment of choice of hemodynamically stable patients. Ann Surg 221: 744-755.
3. Peitzman AB, Makaroun MS, Slasky BS, Ritter P (1986) Prospective study of computed tomography in initial management of blunt abdominal trauma. J Trauma 26: 585-592.
4. Rutledge R, Hunt JP, lentz CW, Fakhry SM, Meyer AA, et al. (1995) A statewide, population-based time-series analysis of the increasing frequency of nonoperative management of abdominal solid organ injury. Ann Surg 222: 311-322.
5. Mirvis SE, Gens DR, Shanmuganathan K (1992) Rupture of the bowel after blunt abdominal trauma: diagnosis with CT. AJR Am J Roentgenol 159: 1217-1221.
6. Rizzo MJ, Fedele MP, Griffiths BG (1989) Bowel and mesenteric injury following blunt abdominal trauma: evaluation with CT. Radiology 173: 143-148.
7. Fischer RP, Miller-Crotchett P, Reed RL (1988) Gastrointestinal disruption: the hazard of non-operative management in adults with blunt abdominal injury. J Trauma 28: 1445-1449.
8. Livingston DH, Lavery RF, Passannante MR, Skurnick JH, Fabian TC, et al. (1998) Admission or observation is not necessary after a negative abdominal computed tomographic scan in patients with suspected blunt abdominal trauma: result of a prospective, multi-institutional trial. J Trauma 44: 273-280.
9. Fang JF, Chen RJ, Lin BC, Hsu YB, Kao JL, et al. (1999) Small bowel perforation: is urgent surgery necessary? J Trauma 47: 515-520.
10. Hulka F, Mullins RJ, Leonardo V, Harrison MW, Silberberg P (1998) Significance of peritoneal fluid as an isolated finding on abdominal computed tomographic scans in pediatric trauma patients. J Trauma 44: 1069-1072.
11. Cunningham MA, Tyroch AH, Kaups KL, Davis JW (1998) Does free fluid on abdominal computed tomographic scan after blunt trauma require laparotomy? J Trauma 44: 599-603.
12. Rodriguez C, Barone JE, Wilbanks TO, Rha CK, Miller K (2002) Isolated free fluid on computed tomogarphic scan in blunt abdominal trauma: a systematic review of incidence and management. J Trauma 53: 79-85.
13. Fang JF, Chen RJ, Lin BC (1998) Cell count ratio: new criterion of diagnostic peritoneal lavage for detection of hollow organ perforation. J Trauma 45: 540-544.
14. Federle MP, Jeffrey RB (1983) Hemoperitoneum studied by computed tomography. Radiology 148: 187-192.
15. Liu M, Lee CH, Peng FK (1993) Prospective comparison of diagnostic peritoneal lavage, computed tomographic scanning, and ultrasonography for the diagnosis of blunt abdominal trauma. J Trauma 35: 267-270.
16. Cook DE, Walsh JW, Vick CW, Brewer WH (1986) Upper abdominal trauma: pitfalls in CT diagnosis. Radiology 159: 65-69.
17. Banz VM, Butt MU, Zimmermann H, Jeger V, Exadaktylos AK (2009) Free abdominal fluid without obvious solid organ injury upon CT imaging: an actual problem or simply over-diagnosing? J Trauma Management & Outcome 15: 3-10.
18. Brasel KJ, Olson CJ, Stafford RE, Johnson TJ (1998) Incidence and significance of free fluid on abdominal computed tomographic scan in blunt trauma. J Trauma 44: 889-892.
19. Ng AK, Simons RK, Torreggiani WC, Ho SGF, Kirkpatrick AW, et al. (2002) Intra-abdominal free fluid without solid organ injury in blunt abdominal trauma: a indication for laparotomy. J Trauma 52: 1134-1140.
20. Drasin TE, Anderson SW, Asandra A, Rhea JT, Soto JA (2008) MDCT evaluation of blunt abdominal trauma: clinical significance of free intraperitoneal fluid in males with absence of identifiable injury. AJR Am J Roentgenol 191: 1821-1826.
21. Venkatesh KR, McQuay N Jr (2007) Outcome of management in stable children with intra-abdominal free fluid without solid organ injury after blunt abdominal injury. J Trauma 62: 216-220.
22. Gonser-Hafertepen LN, Davis JW, Bilello JF, Ballow SL, Sue LP, et al. (2014) Isolated free fluid on abdominal computed tomography in blunt trauma: watch and wait or operate ? J Am Coll Surg 219: 599-605.
23. Holmes JF, London KL, Brant WE, Kuppermann N (2007) Isolated intraperitoneal fluid on abdominal computed tomography in children with blunt trauma. Acad Emerg Med 7: 335-341.
24. Malhotra AK, Fabian TC, Katsis SB, Gavant ML, Croce MA (2000) Blunt bowel and mesenteric injuries: the role of screening computed tomography. J Trauma 48: 991-1000.
25. Levine CD, Patel UJ, Wachsberg RH, Simmons MZ, Baker SR, et al. (1995) CT in patients with blunt abdominal trauma: clinical significance of intraperitoneal fluid detected on a scan with otherwise normal findings. AJR Am J Roentgenol 164: 1381-1385.
26. Eanniello VC, Gabram SGA, Eusebio R, Jacobs LM (1994) Isolated free fluid on abdominal computerized tomographic scan: an indication for surgery in blunt trauma patients? Conn Med 58: 707-710.
27. Sherck J, Shatney C, Sensaki K, Selivanov V (1994) The accuracy of computed tomography in the diagnosis of blunt small-bowel perforation. Am J Surg 168: 670-675.
28. Ruchholtz S, Waydhas C, Lewan U, Pehle B, Taeger G, et al. (2004) Free abdominal fluid on ultrasound in unstable pelvic ring fracture: Is laparotomy always necessary? J Trauma 57: 278-286.
29. Friese RS, Malekzadeh S, Shafi S, Gentilello LM, Starr A (2007) Abdominal ultrasound is an unreliable modality for the detection of hemoperitoneum in patients with pelvic fracture. J Trauma 63: 97-102.
30. Verbeek D, Sugrue M, Balogh Z, Cass D, Civil I, Harris I, et al. (2008) Acute management of hemodynamically unstable pelvic trauma patients: Time for a change? Multicenter review of recent practice. World J Surg 32: 1874-1882.
31. Mahmood I, Tawfek Z, Abdelrahman Y, Siddiuqqi T, Abdelrahman H, et al. (2014) Significance of computed tomography finding of intra-abdominal free fluid without solid organ injury after blunt abdominal trauma: time for laparotomy on demand. World J Surg 38: 1411-1415.