Isolated Free Fluid on Abdominal Computed Tomography in Blunt Trauma: Watch and Wait or Operate?

Laura N Gonser-Hafertepen, DO, James W Davis, MD, FACS, John F Bilello, MD, FACS, Shana L Ballow, DO, Lawrence P Sue, MD, FACS, Kathleen M Cagle, FNP-C, Chandrasekar Venugopal, MD, DABR, Stephen C Hafertepen, MD, Krista L Kaups, MD, FACS

BACKGROUND: Isolated free fluid (FF) on abdominal CT in stable blunt trauma patients can indicate the presence of hollow viscus injury. No criteria exist to differentiate treatment by operative exploration vs observation. The goals of this study were to determine the incidence of isolated FF and to identify factors that discriminate between patients who should undergo operative exploration vs observation.

STUDY DESIGN: A review of blunt trauma patients at a Level I trauma center from July 2009 to March 2012 was performed. Patients with a CT showing isolated FF after blunt trauma were included. Data collected included demographics, injury severity, physical examination, CT, and operative findings.

RESULTS: Two thousand eight hundred and ninety-nine patients had CT scans, 156 (5.4%) of whom had isolated FF. The therapeutic operative group included 13 patients; 9 had immediate operation and 4 failed nonoperative management. The nonoperative/nontherapeutic operation group consisted of 142 patients with successful nonoperative management and 1 patient with a nontherapeutic operation. Abdominal tenderness was documented in 69% of the therapeutic operative group and 23% of the nonoperative/nontherapeutic group (odds ratio = 7.5; $p < 0.001$). The presence of a moderate to large amount of FF was increased in the therapeutic operative group (85% vs 8%; odds ratio = 66; $p < 0.001$).

CONCLUSIONS: Isolated FF was noted in 5.4% of stable blunt trauma patients. Blunt trauma patients with moderate to large amounts of FF without solid organ injury on CT and abdominal tenderness should undergo immediate operative exploration. Patients with neither of these findings can be safely observed. (J Am Coll Surg 2014;219:599–605. © 2014 by the American College of Surgeons)

Isolated free fluid (FF) identified on abdominal/pelvic CT in the stable adult blunt trauma patient presents a management dilemma. Free fluid without solid organ injury (SOI) might be an important clue to the presence of hollow viscus or mesenteric injury, which has a considerable risk of morbidity and mortality if diagnosis is delayed.[1-4] In 1998, Cunningham and colleagues recommended mandatory laparotomy for the CT finding of FF without SOI or signs of bowel injury.[5] Some studies concurred,[6-8] but others proposed that these patients should instead be carefully observed with serial abdominal examinations and laboratory studies, with the understanding that a minority of patients would fail nonoperative management.[9-12]

During the last decade, multi-detector CT (MDCT) has been routinely available at most trauma centers. Because earlier studies were performed using single-detector CT (10-mm images), use of MDCT would theoretically allow identification of more injuries with higher-quality, thinner images (2.5 to 5 mm). However, MDCT has not proven to be more sensitive or specific for the diagnosis of hollow viscus or mesenteric injury,

CME questions for this article available at http://jacscme.facs.org

Disclosure Information: Authors have nothing to disclose. Timothy J Eberlein, Editor-in-Chief, has nothing to disclose.

Presented at the Western Trauma Association 43rd Annual Meeting, Snowmass, CO, March 2013.

Received March 4, 2014; Revised April 8, 2014; Accepted April 15, 2014.

From the University of California San Francisco, Fresno, Community Regional Medical Center, Fresno, CA.

Correspondence address: Laura N Gonser-Hafertepen, DO, Department of Surgery, University of California San Francisco, Fresno, Community Regional Medical Center, 2823 Fresno St, 1st Fl, Fresno, CA 93721. email: lgonser@fresno.ucsf.edu

http://dx.doi.org/10.1016/j.jamcollsurg.2014.04.020
ISSN 1072-7515/14

Abbreviations and Acronyms

FAST = Focused Assessment with Sonography for Trauma
FF = free fluid
MDCT = multi-detector CT
OR = odds ratio
SOI = solid organ injury

and isolated FF remains an important indicator of the possibility of underlying pathology.[13] Initial retrospective reviews from radiology literature done in male patients have shown a higher rate of isolated FF with MDCT and report that most of the patients underwent successful nonoperative management.[11,12]

Consensus has still not been reached on the finding of isolated FF, as demonstrated by a survey of the members of the American Association for the Surgery of Trauma, which showed considerable variation with regard to diagnostic approach and treatment for patients with this finding.[14] No previous studies have identified characteristics to differentiate between stable blunt trauma patients with isolated FF who should undergo operative exploration vs those that can be managed safely with careful observation.

The goals of this study were to determine the frequency of isolated FF in stable blunt trauma patients since the integration of MDCT and identification of characteristics to discriminate between patients who should undergo immediate operative exploration vs those that might be carefully observed.

METHODS

A retrospective review was conducted of blunt trauma patients, aged 16 years and older, presenting to Community Regional Medical Center in Fresno, California from July 1, 2009 through March 31, 2012. Community Regional Medical Center is an American College of Surgeons—verified Level I trauma center with approximately 3,500 trauma patients evaluated annually. All patients in the Trauma Registry who had abdominal/pelvic CT scan after sustaining blunt trauma were reviewed. The standardized CT protocol at our institution uses a 64-slice helical MDCT (General Electric Company), using approximately 100 mL Omnipaque intravenous contrast, with 2.5-mm slices through the thorax and abdomen through the level of T-12 and 5-mm slices through the remainder of the abdomen and pelvis.

Computed tomography scans were initially reviewed by the trauma surgery attending and senior surgical resident/fellow, as well as the emergency department physicians. Computed tomography scans were then read by an on-site group of experienced trauma radiologists. Final interpretations by the radiologists were reconciled with those of the trauma service, usually within 12 hours of admission. Any discrepancies were discussed and patient care was modified as appropriate. The decision for immediate operation vs careful observation was at the discretion of the attending trauma surgeon at the time of admission.

Table 1. Free Fluid Grading System

Amount of free fluid	Definition
Trace	Fluid in 1 slice* of 1 region†
Small	Fluid in 1 to 3 slices of 1 region
Moderate	Fluid in 1 to 3 slices of >2 regions, or fluid in >4 slices of 1 region
Large	Fluid in multiple regions of multiple slices

*1 slice = 5 mm.
†Regions are defined as pelvis, right pericolic gutter, left pericolic gutter, perisplenic, perinephric (retroperitoneal), within bowel loops, and other.

The patient cohort in this study was defined by reviewing the radiologist's final read via electronic medical record. Patients with FF and no sign of SOI or hollow viscus injury (defined as bowel wall thickening, contrast extravasation, or extraluminal air) were included in the study. Each CT scan identified to have isolated FF without SOI was reviewed by the Chief of Trauma (JWD) and a senior radiologist (CV) using a standardized grading system.

No universally accepted grading system has been defined for describing the amount of FF seen on CT. For this investigation, the amount of FF was classified as follows: Trace FF is fluid in 1 slice of 1 region; small FF is in 1 to 3 slices in 1 region; moderate FF is fluid in >4 slices in 1 region or 1 to 3 slices in 2 regions; and large FF is fluid seen in multiple slices in multiple regions. Abdominal regions were separated into pelvis, right pericolic gutter, left pericolic gutter, perisplenic, perinephric (retroperitoneal), within bowel loops, and other (Table 1). Hounsfield units were only sporadically mentioned in the radiology reports and were not reviewed because they have not been routinely mentioned in earlier publications on this topic.

Patients were excluded from the study if they were deemed hemodynamically unstable (ie, emergency department systolic blood pressure <90 mmHg, prehospital hypotension, and/or positive Focused Assessment with Sonography for Trauma [FAST] in patients with base deficit less than −6[15]). Those patients in whom the CT was performed outside of the standard protocol or at an outside institution were also excluded. Patients with clinical indications for immediate laparotomy (eg, peritonitis, traumatic abdominal wall hernia, etc) and those with CT evidence of SOI (ie, liver, spleen, or kidney) or hollow

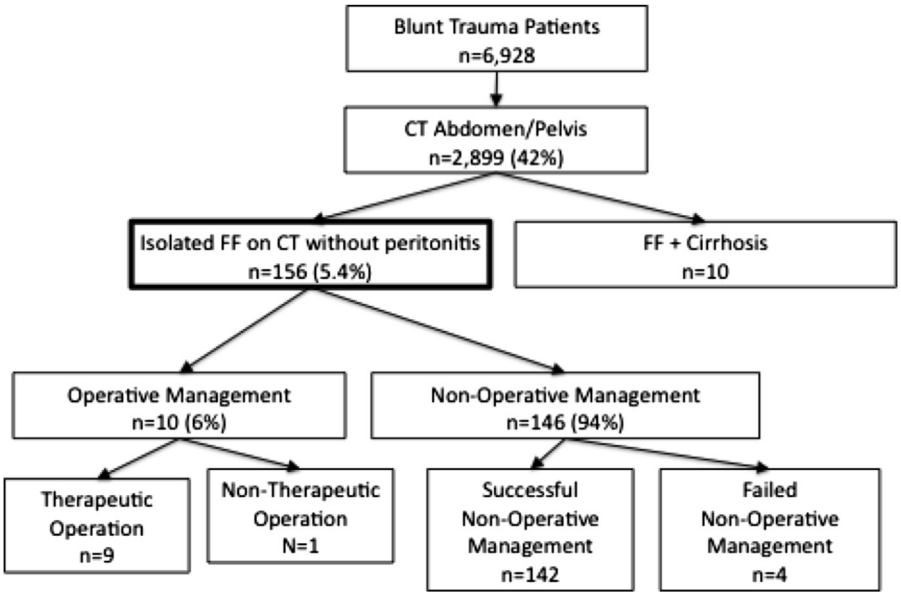

Figure 1. Flow diagram of patients with isolated free fluid (FF).

viscus injury (ie, bowel wall thickening, contrast extravasation, or extraluminal air) were not included.

Initial abdominal examination was determined by review of the physical examination documentation in the medical record from the trauma surgery team member who evaluated the patient. If the record showed peritonitis, involuntary guarding, or rebound tenderness, the patient was considered to have peritoneal signs and was not included in the cohort.

The following data were collected for each patient: age, sex, ethnicity, mechanism of injury, initial Glasgow Coma Scale score, initial abdominal examination, presence/absence of abdominal wall contusions (eg, seatbelt sign), associated injuries, FAST examination results, CT final interpretation by the radiologist, Abbreviated Injury Scale for Abdomen, Injury Severity Score, operative findings and interventions when applicable, length of stay, and outcomes.

Data analysis was performed using the Mann-Whitney U test, Fisher's exact test, chi-square analysis and Mantel-Haenszel odds ratio (OR). Data are expressed as mean $\pm$ SD with significance attributed to $p < 0.05$. Institutional Review Board approval was obtained from the University of California San Francisco, Fresno and Community Regional Medical Centers.

RESULTS

During the study period, 6,928 blunt trauma patients were evaluated by our trauma service. Two thousand eight hundred and ninety-nine (42%) had abdominal/pelvic CT as part of their initial evaluation. One hundred and sixty-six patients had isolated FF on CT scan without other indications for surgery. Ten of these 166 patients had FF and either a clinical history or CT evidence of cirrhosis and were subsequently excluded. The remaining 156 patients (5.4%) made up the study cohort; of this group, 10 (6%) underwent immediate operative exploration and 146 (94%) had initial nonoperative management. Four failed nonoperative management (Fig. 1).

To evaluate characteristics differentiating patients that required surgery vs those that did not, the study population was separated into two groups for data analysis. The therapeutic operative group consisted of 13 patients; those patients who underwent immediate therapeutic operation (9 patients) and those who failed nonoperative management (4 patients). The nonoperative/nontherapeutic group consisted of 143 total patients; 142 patients with successful nonoperative management and 1 patient with a diagnostic but nontherapeutic operation.

There was no significant difference in age, sex, ethnicity, mechanism of injury, or initial Glasgow Coma Scale score between therapeutic operative and nonoperative/nontherapeutic groups. The majority of patients were involved in motor-vehicle or motorcycle crashes (74%). Other mechanisms of injury included fall from height (8%), pedestrian vs auto (6%), assault (6%), ground-level fall (3%), and others (3%). Patients in the therapeutic operative group were more severely injured than those in the nonoperative/nontherapeutic group, as reflected by a higher

Table 2. Demographics of Patients with Isolated Free Fluid on Abdominal Computed Tomography Scan

	Total (n = 156)	Therapeutic operation (n = 13)	Nonoperative or nontherapeutic operation (n = 143)	p Value
Age, y, mean	35	33 ± 13*	36 ± 18*	NS
Ethnicity, n (%)				
Hispanic	67 (43)	6 (46)	61 (43)	NS
White	63 (40)	4 (31)	59 (41)	NS
Asian	11 (7)	1 (8)	10 (7)	NS
African American	5 (3)	0 (0)	5 (3)	NS
Other/not specified	10 (6)	2 (15)	8 (6)	NS
Mechanism of injury, n (%)				
Motor vehicle crash	109 (70)	11 (85)	98 (69)	NS
Motorcycle crash	7 (4)	2 (15)	5 (3.5)	NS
Fall from height	13 (8)	0	13 (9)	NS
Pedestrian vs auto	9 (6)	0	9 (6)	NS
Assault	9 (6)	0	9 (6)	NS
Ground-level fall	4 (3)	0	4 (3)	NS
Other	5 (3)	0	5 (3.5)	NS
Initial GCS score	13	13 ± 5*	13 ± 4*	NS
Hospital LOS	7	7 ± 7*	7 ± 10*	NS
Injury severity, mean				
ISS	14	18 ± 18*	14 ± 12*	0.02
Abdominal AIS	1	2.2 ± 1*	0.5 ± 0.9*	<0.001

*Values are mean ± SD.
AIS, Abbreviated Injury Scale; GCS, Glasgow Coma Scale; ISS, Injury Severity Score; LOS, length of stay.

Abbreviation Injury Score for Abdomen (2.2 ± 1 vs 0.5 ± 0.9; $p < 0.001$) and Injury Severity Score (18 ± 18 vs 14 ± 12; $p = 0.02$) (Table 2).

The most common injuries noted at operative exploration were small intestinal enterotomies in 5 patients. Four patients had intraperitoneal bladder injuries. Three of the 4 patients with bladder rupture had strong clinical suspicion or confirmation of bladder rupture based on hematuria and/or cystogram. Other findings at time of operation in single patients with FF and no SOI included a ruptured ovarian cyst, mesenteric laceration, splenic laceration, and pancreatic injury.

One patient underwent an immediate diagnostic but nontherapeutic operation. He was a 16-year-old male who sustained a fall when mountain biking, hitting his abdomen on the handlebars. He had stable vital signs and isolated abdominal pain. On abdominal examination, he had left upper quadrant tenderness. A FAST examination was not performed. Computed tomography showed a small amount of FF and possible duodenal edema. He was taken to the operating room because of abdominal tenderness in combination with FF. Diagnostic laparoscopy was performed and he was found to have a small bowel mesenteric hematoma without active hemorrhage and with viable bowel. He was discharged home on hospital day 2 without complication.

Characteristics of the isolated FF seen on CT were evaluated. Isolated FF in the pelvis only was associated with successful nonoperative management ($p < 0.001$). Increasing amounts of FF were associated with the need for surgery. Specifically, the presence of a moderate to large amount of FF was significantly more common in patients undergoing therapeutic operative intervention (85% vs 8%; OR = 66; $p < 0.001$). Trace FF was noted in 20 patients, and none required laparotomy, however, this was not statistically significant (Tables 3, 4).

Abdominal tenderness was noted in 69% of the patients who underwent therapeutic operation, and it was found in only 23% of those in the nonoperative/nontherapeutic group (OR = 7.5; $p < 0.001$). The presence of abdominal wall contusion did not differentiate between the two groups (Table 4). Positive and negative predictive values were calculated for abdominal tenderness, moderate to large FF on CT and for both tenderness and moderate to large FF (Table 5).

Focused Assessment with Sonography for Trauma examination results were found in 61% (95 of 156) of patients in the study cohort. Focused Assessment with Sonography for Trauma was more likely to be positive as the amount of FF increased (Table 6).

All 4 patients that failed nonoperative management had motor-vehicle crash as their mechanism of injury

Table 3. Location and Amount of Free Fluid

Location and amount of FF	Therapeutic operation (n = 13)		Nonoperative or nontherapeutic operation (n = 143)		p Value
	n	%	n	%	
Location of FF on CT					
Pelvis only	3	23	106	74	<0.001
Pelvis + other location(s)	5	38.5	4	3	<0.001
Other location(s) only	5	38.5	33	23	NS
Amount of FF on CT					
Trace	0		20	14	NS
Small	2	15	112	78	<0.001
Moderate	7	53	11	8	<0.001
Large	4	31	0		<0.001

FF, free fluid.

and were found to have small bowel injuries. The time to operating room ranged from 8 hours to 11 days from the time of initial trauma team evaluation. The first was a 52-year-old female who had a small amount of perihepatic FF on CT, negative FAST, and no abdominal tenderness or contusion. Peritonitis and a decrease in hemoglobin developed 8 hours after admission. At laparotomy, she had multiple jejunal perforations, which were resected; she had no postoperative complications.

The second was a 17-year-old male who presented with mild abdominal tenderness, a small amount of FF in the pelvis on CT, and a negative FAST; his pain increased after 3 days of observation, leading to repeat imaging that demonstrated free air. At exploration, he had a jejunal injury that was primarily repaired. He was readmitted twice during the first 30 postoperative days for partial small bowel obstruction that resolved with nonoperative measures.

The third patient was a 46-year-old male with a moderate amount of perihepatic FF, a positive FAST, and some initial tenderness without abdominal wall contusion. His tenderness resolved, he tolerated a diet, and was discharged home after 2 days. He returned to the hospital on post-injury day 11 with peritonitis and was found to have a large ileal defect and underwent resection with end ileostomy. He had a prolonged ICU course for intra-abdominal sepsis and was actually the inspiration for this study.

The fourth patient was a 40-year-old woman with abdominal tenderness, no abdominal wall contusions, moderate amount of FF on CT, and no FAST performed. She tolerated a regular diet and was discharged home after 5 days. She returned to the hospital with peritonitis on post-injury day 7 and was found to have multiple small intestinal perforations. She had a complex postoperative course with intra-abdominal sepsis and enterocutaneous fistulae.

DISCUSSION

Evaluation of the abdomen in a stable blunt trauma patient with isolated FF on CT scan continues to be a potentially challenging clinical problem. This investigation confirmed the initial reports from the radiology literature by demonstrating an increase in identification of isolated FF since integration of MDCT than was seen with single-detector CT scanners (5.4% vs <4%[5-10]). With this increasing identification, management of the stable blunt trauma patient with isolated FF continues to be a relevant clinical scenario for surgeons. This is the largest single-institution report of blunt trauma patients with isolated FF on CT, and the only in the trauma surgical literature since widespread incorporation of MDCT. Unfortunately, MDCT has not proven to be more sensitive or specific in the diagnosis of hollow viscus or mesenteric injury, and isolated FF remains an important indicator of the possibility of underlying hollow viscus or mesenteric injury.[13]

Proposed management schemes of patients with isolated FF and no other operative indications have followed one of two approaches, either operative exploration for all patients, with anticipation of some negative laparotomies, or close observation and acceptance of some failures of nonoperative management.[5-10] Although mandatory laparotomy does reduce the risk of missed injury, negative laparotomy carries a considerable risk of complications, including atelectasis, ileus, pneumonia, wound infection, and subsequent small bowel obstruction.[16,17] This

Table 4. Initial Examination Predictors of Therapeutic Operative Intervention

Examination predictors	Therapeutic operation (n = 13)		Nonoperative or nontherapeutic operation (n = 143)		p Value	OR (95% CI)
	n	%	n	%		
Abdominal tenderness	9	69	33	23	<0.001	7.5 (2.2–25.9)
Abdominal contusion	3	23	21	15	NS	NA
Moderate to large FF on CT	11	85	11	8	<0.001	66 (12.9–335.9)
Tenderness and moderate to large FF	8	62	5	3	<0.001	44.2 (10.6–184.5)

FF, free fluid; NA, not applicable; OR, odds ratio.

Table 5. Positive and Negative Predictive Values of Initial Workup Characteristics in Predicting Operative Intervention

	PPV (therapeutic operation), %	NPV (successful nonoperative and nontherapeutic operations), %
Isolated FF plus:		
Tenderness*	21	96
Moderate to large FF on CT	50	99
Tenderness and moderate to large FF on CT	62	97

*Abdominal tenderness without peritonitis.
FF, free fluid; NPV, negative predictive value; PPV, positive predictive value.

investigation confirms previous studies suggesting that the majority of patients with isolated FF without SOI can be managed safely with careful observation (serial abdominal examinations and laboratory studies) and a low threshold for operative intervention.[9-12]

In our patient population, the vast majority of patients with isolated FF underwent successful nonoperative management (91%). Unlike earlier studies, we sought to identify characteristics differentiating between patients who should have operative exploration vs those that should undergo careful observation. The amount of FF and the presence of abdominal tenderness were found to be important indicators of the need for surgical intervention. No patient with trace FF required operative intervention, but a moderate to large amount of FF on CT (OR = 66; $p < 0.001$) and abdominal tenderness (OR = 7.5; $p < 0.001$) were independent predictors of the need for operative intervention. A moderate to large amount of fluid on CT had a positive predictive value of 50%, and abdominal tenderness had a positive predictive value of 21% for operative intervention. However, when placed in combination, tenderness plus a moderate to large amount of FF had a positive predictive value of 62%.

Our investigation is prone to all the limitations of retrospective studies. The CT scans were read by a number of radiologists and did not use a universally standardized grading system for quantifying the amount of FF. To standardize this, we reviewed each of the CT scans and created a standard grading system, as one does not exist in the literature (see Methods section). Hounsfield units were only sporadically mentioned in the radiology reports and were not reviewed because they have not been routinely mentioned in earlier publications on this topic.

The patients with bladder rupture could potentially be excluded from this analysis. Three of the 4 had hematuria at time of Foley catheter placement. Two of these had a preoperative cystogram that demonstrated intraperitoneal bladder rupture. The third patient did not undergo cystography, as the decision had been made for operative management. There was no documentation of hematuria on the fourth patient. Overall, 3 of the 4 patients with bladder rupture had strong clinical suspicion or confirmation of bladder rupture based on hematuria and/or cystogram. These patients were included because they are an important subgroup of patients who require operation in the setting of isolated FF without SOI.

The experience and expertise of examiners performing the initial abdominal examination also varied, ranging from seasoned physicians assistants and senior faculty members to junior surgical residents or nonsurgical rotating residents.

The use of diagnostic peritoneal lavage or diagnostic peritoneal aspirate was not investigated in this patient cohort.[18,19] Diagnostic peritoneal lavage or diagnostic peritoneal aspirate might be useful in patients with isolated FF if it reveals clear indications for operative exploration (enteric contents or bilious fluid). However, the experience at our institution has shown that diagnostic peritoneal aspirate might be nondiagnostic if only a small amount of blood is aspirated. Diagnostic peritoneal lavage can be similarly nondiagnostic.

Table 6. Correlation of Focused Assessment Sonography for Trauma Result with Amount of Free Fluid on Computed Tomography

Amount of FF on CT	Positive FAST (n = 12)		Negative FAST (n = 83)		
	n	%	n	%	p Value
Trace	1	8	10	12	NS
Small	4	33	62	75	0.01
Moderate	5	38	10	12	NS (0.052)
Large	2	17	1	1	0.048

FAST, Focused Assessment Sonography for Trauma; FF, free fluid.

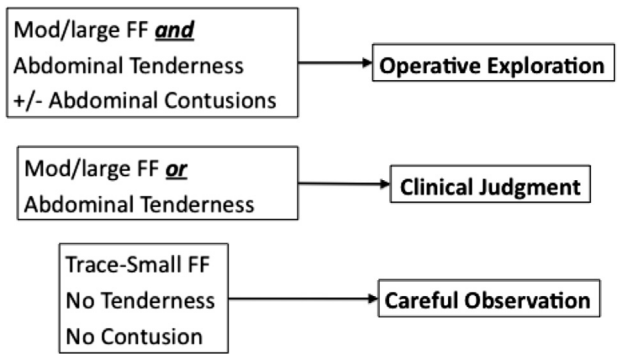

Figure 2. Recommendations for stable blunt trauma patients with isolated free fluid (FF) on CT scan. Mod/Large, moderate to large.

Based on the findings from this study, we recommend the following guidelines for management of the stable blunt trauma patient with isolated FF on CT. Patients with a moderate to large amount of FF on CT and abdominal tenderness (with or without abdominal wall contusion) should undergo operative exploration. Patients with a trace to small amount of FF and no abdominal tenderness are unlikely to require operative intervention and should be carefully observed with serial abdominal examinations and laboratory studies. Those patients with either a moderate to large amount of isolated FF or abdominal tenderness are more likely to require an operation than those without those findings, and the decision for operative exploration should be made based on careful clinical judgment (Fig. 2).

If the proposed criteria were used in our patient cohort, none of the patients in the successful nonoperative management group fit the criteria to undergo immediate laparotomy. In the failed nonoperative management group, 2 of the 4 patients would have instead been treated with an immediate operation, as they had both tenderness and a moderate amount of FF. Another of the failed nonoperative patients had tenderness, but only a small amount of FF. The fourth failed nonoperative patient had neither criteria for operation. The patients who underwent the nontherapeutic operation had only tenderness and might have still undergone immediate operative exploration.

CONCLUSIONS

We recommend that blunt trauma patients with moderate to large amount of FF without SOI on CT scan and with abdominal tenderness undergo immediate operative exploration. Patients without these findings should be carefully observed.

Author Contributions

Study conception and design: Gonser-Hafertepen, Davis, Bilello, Sue

Acquisition of data: Gonser-Hafertepen, Bilello, Ballow, Sue, Cagle, Venugopal, Hafertepen

Analysis and interpretation of data: Gonser-Hafertepen, Davis, Ballow, Sue, Cagle

Drafting of manuscript: Gonser-Hafertepen, Davis, Ballow, Cagle, Kaups

Critical revision: Gonser-Hafertepen, Davis, Bilello, Ballow, Sue, Venugopal, Hafertepen, Kaups

REFERENCES

1. Allen G, Moore F, Cox C, et al. Hollow visceral injury and blunt trauma. J Trauma 1998;45:69–77.
2. Maull K, Reath D. Impact of early recognition on outcome in nonpenetrating wounds of the small bowel. South Med J 1984;77:1075–1077.
3. Sherck J, Shatney C, Sensaki K, Selivanov V. The accuracy of computed tomography in the diagnosis of blunt small-bowel perforation. Am J Surg 1994;168:670–675.
4. Fakhry S, Brownstein M, Watts M, et al. Relatively short diagnostic delays (<8 hours) produce morbidity and mortality in blunt small bowel injury: an analysis of time to operative intervention in 198 patients from a multicenter experience. J Trauma 2000;48:408–415.
5. Cunningham M, Tyroch A, Kaups K, Davis J. Does free fluid in abdominal computed tomographic scan after blunt trauma require laparotomy? J Trauma 1998;44:599–603.
6. Ng A, Simons R, Torreggiani W, et al. Intra-abdominal free fluid without solid organ injury in blunt abdominal trauma: an indication for laparotomy. J Trauma 2002;52:1134–1140.
7. Brasel K, Olson C, Stafford R, Johnson T. Incidence and significance of free fluid on abdominal computed tomographic scan in blunt trauma. J Trauma 1998;44:889–892.
8. Yegiayants S, Abou-Lahoud G, Taylor E. The management of blunt abdominal trauma patients with computed tomography scan findings of free peritoneal fluid and no evidence of solid organ injury. Am Surg 2006;72:942–946.
9. Livingston D, Lavery R, Passannate M, et al. Free fluid on abdominal computed tomography without solid organ injury after blunt abdominal injury does not mandate celiotomy. Am J Surg 2001;182:6–9.
10. Rodriguez C, Barone J, Wibanks T, et al. Isolated free fluid on computed tomographic scan in blunt abdominal trauma: a systematic review of incidence and management. J Trauma 2002;53:79–85.
11. Yu J, Fulcher A, Wang A, et al. Frequency and importance of small amount of isolated pelvic free fluid detected with multidector CT in male patients with blunt trauma. Radiology 2010;256:799–805.
12. Drasin T, Anderson S, Asandra A, et al. MDCT Evaluation of blunt abdominal trauma: clinical significance of free intraperitoneal fluid in males with absence of identifiable injury. AJR Am J Roentgenol 2008;191:1821–1826.
13. Ekeh P, Saxe J, Walusimbi M, et al. Diagnosis of blunt intestinal and mesenteric injury in the era of multidetector CT technology—are results better? J Trauma 2008;65:354–359.
14. Brownstein M, Bunting T, Meyer A, Fakhry S. Diagnosis and management of blunt small bowel injury; a survey of the membership of the American Association for the Surgery of Trauma. J Trauma 2000;48:403–407.
15. Bilello JF, Davis JW, Lemaster D, et al. Prehospital hypotension in blunt trauma: identifying the "crump factor". J Trauma 2011;70:1038–1042.
16. Morrison J, Wisner D, Bodai B. Complications after negative laparotomy for trauma: long-term follow-up in a health maintenance organization. J Trauma 1996;41:509–513.
17. Renz B, Feliciano D. Unnecessary laparotomies for trauma: a prospective study of morbidity. J Trauma 1995;38:350–356.
18. Gonzalez R, Ickler J, Gachassin P. Complementary roles of diagnostic peritoneal lavage and computed tomography in the evaluation of blunt abdominal trauma. J Trauma 2001; 51:1128–1136.
19. Davis J, Hoyt D, Mackersie R, et al. Complications in evaluating abdominal trauma: diagnostic peritoneal lavage versus computed axial tomography. J Trauma 1990;30:1506–1509.