Blunt Abdominal Trauma Patients: Can Organ Injury Be Excluded without Performing Computed Tomography?

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Purpose: **The purpose of this study was to determine whether admission non-computed tomography (CT) criteria can exclude intra-abdominal injury in stable patients sustaining blunt abdominal trauma.**

Methods: **Seven hundred fourteen hemodynamically stable patients with suspicion of blunt abdominal trauma were included in the study. Admission data for clinical examination, sonography, routine laboratory studies, chest/pelvic radiographic findings, and Glasgow Coma Scale (GCS) score were recorded. Each patient underwent helical abdominal CT. Injuries were considered major if they required surgery or angiographic intervention. At the authors' institution, angiography is routinely performed if there is a splenic injury of American Association for the Surgery of Trauma grade II or higher or a liver injury of American Association for the Surgery of Trauma grade III or higher. Statistical analysis was performed to determine the value of isolated and combined clinical, radiologic, and laboratory parameters in depicting an intra-abdominal injury with regard to CT results and clinical follow-up.**

Results: **The best combination of criteria to identify a major abdominal injury was obtained when sonography, chest radiography, and three laboratory parameters (serum glutamic oxaloacetic transaminase, white blood cell count, and hematocrit) were normal: 22% (129 of 589) of patients without major injuries fulfilled these criteria. The only combination of criteria that completely excluded intra-abdominal injury was obtained when clinical criteria combined with a Glasgow Coma Scale score > 13, bedside radiologic studies, and laboratory data were all normal, but only 12% (68 of 578) of patients without abdominal injury fulfilled these criteria.**

Conclusion: **After blunt abdominal trauma, admission non-CT criteria can at best identify 12% of patients without intra-abdominal injuries and 22% of patients without major injuries.**

Key Words: **Abdomen, Trauma, Ultrasound, Computed tomography (CT), Triage, Use.**

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It is generally accepted currently that hemodynamically stable blunt abdominal trauma patients with an abnormal clinical abdominal examination require abdominal computed tomography (CT) for further evaluation.[1,2] However, a benign physical examination alone has been shown to be unreliable for excluding intra-abdominal injuries.[3–7] Therefore, the management of patients with a normal abdominal clinical examination after blunt trauma is a subject of controversy.[1,4,5] The wide availability of CT as well as the constant technical improvements in image quality and speed, such as helical or multislice helical CT, can easily foster overuse and perhaps overdependence on CT results for planning management of these patients. Although CT is an excellent diagnostic tool for abdominal trauma assessment, it is nonetheless costly, requires radiation exposure, and removes the patient briefly from direct clinical care. In busy trauma or emergency facilities, overuse of CT can lead to inappropriate delays in patient care.

The requirement for more cost-effective use of health care resources has created the need for more rational use of expensive testing by careful selection of patients for high-technology imaging studies. Some authors[8,9] advocate an initial sonographic examination as the primary diagnostic tool used as an extension of the clinical examination in initial assessment of stable blunt abdominal trauma patients. Other studies[1,2,5,10] emphasize the need for an evaluation based on clinical criteria, chest or pelvis radiography, laboratory results such as arterial base deficit, or gross hematuria to determine the need for abdominal CT. However, most of these authors observe a 12- to 24-hour period of clinical abdominal observation before discharging a patient without performing abdominal CT. In some centers,[11] clinical observation along with non-CT radiologic investigations has been shown to be less cost-effective than performing an abdominal CT in every patient admitted after blunt abdominal trauma. Indeed, a negative abdominal computed tomographic scan has been reported reliable enough to safely discharge a patient without further observation or investigations if there is no other (extra-abdominal) indication for hospitalization.[12]

The purpose of the present study is to analyze typically performed pre-CT clinical, radiologic, and laboratory studies

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used by members of admitting teams in a trauma center to determine their distinct or combined value in identifying or excluding intra-abdominal injuries as compared with subsequent CT results. This analysis is based on admission findings only and not on serial examinations, with a goal toward determination of criteria to allow discharge of blunt trauma patients (or at least consider them free of intra-abdominal injury) without performing other investigations, including CT or clinical follow-up.

PATIENTS AND METHODS

Data Collection

This study was performed in a prospective manner during an 18-month period at a Level I trauma center with an annual admission volume of more than 7,000 patients. The patient population of interest consisted of men and women of all ethnic and racial groups from 13 years of age or older, in whom contrast-enhanced helical CT examination was requested because of a history or clinical suspicion of blunt abdominal trauma. Study protocol forms were given to admitting teams members to provide information on admission examination findings before abdominal CT. The information requested included the patient's admitting vital signs (pulse, blood pressure, respiration, and Glasgow Coma Scale [GCS] score). Specific clinical findings concerning the abdominal physical examination were also recorded, including tenderness to palpation, rebound, guarding, as well as the presence of abdominal distention, body-wall contusion, or seat belt mark. The presence of other major nonabdominal injuries (distracting injuries) was also recorded. The clinical examination findings were recorded for patients regardless of the admitting GCS score. Chest and pelvic radiographs are routinely performed at admission of blunt trauma victims and interpreted by radiologists. Pelvic and chest radiography results were based on the official radiology report. A limited abdominal sonographic examination, or focused assessment sonography for trauma (FAST), was performed and interpreted in the trauma resuscitation area during initial clinical assessment by a member of the surgical team under supervision of a FAST-certified fellow or attending surgeon. FAST was performed with a Siemens Sonoline Model SI-400 (Siemens Medical Systems, Iselin, NJ) using a 12-inch monochrome display monitor and a 3.5-MHz convex sector transducer. FAST was used for detection of free peritoneal fluid in three regions of the abdomen: the right upper quadrant, with particular attention to the hepatorenal fossa (Morison's pouch); the left upper quadrant (subphrenic space and splenorenal recess); and the pelvis, with attention to the pouch of Douglas. FAST was usually performed before a Foley catheter was placed. When the bladder was empty, it was not a requirement to fill it with fluid before FAST. The FAST study was interpreted as positive if free intraperitoneal fluid was found in any of the scanned regions, negative if no free fluid was detected, or indeterminate if one or more of the regions were not adequately visualized and no fluid was depicted in the other regions. No estimate of the quantity of peritoneal fluid depicted by sonography was obtained. The presence or absence of pericardial or pleural fluid or parenchymal injury was not considered. The radiology staff did not review the results of the FAST examinations. The result of the FAST examination was recorded on the written form before performing abdominopelvic CT.

Blunt trauma patients usually had a standard hematologic evaluation performed in the trauma center laboratory. All laboratory results were available within 30 minutes after the blood sample was delivered, except for toxins and urinalysis, which were performed in another location. Data collected included hematocrit (HCT), white blood cell count (WBC), lactate, amylase, and serum glutamic oxaloacetic transaminase (SGOT) levels. The presence or absence of gross hematuria was recorded.

Immediately before performing CT, the trauma team physician responsible for the patient (usually the fellow or senior surgical resident) was asked to record a "personal impression" concerning what the result of the CT would be, on the basis of all the available parameters cited above. There were five points attributed to the estimated risk for abdominal injury by CT: 1 = no suspicion to 5 = high suspicion. However, because these predictions were both partly subjective and partly based on the available objective data described above, they were not considered as a distinct objective variable in the statistical analysis (see below) and are given only for the purpose of comparison.

Initial abdominal CT was performed within 24 hours after the patient's admission (typically $<$ 2 hours). Helical CT was performed using a Siemens Somaton Plus 4 (Siemens Medical Systems). Scanning was routinely performed with intravenous contrast enhancement using a power-injected bolus of 150 mL of 240 mg of iodine per milliliter injected at 3 mL/s. A uniphasic injection with a scan delay of 60 seconds from the time of initiation of the intravenous contrast injection was used. Whenever possible, based on clinical circumstances, oral contrast material was given: 1% hypaque (diatrizoate sodium) at a dose of 450 mL 30 minutes before scanning and an additional 450 mL immediately before scanning. CT was performed from the lung bases to the pelvis with 8-mm contiguous sections, and with a table speed of 8 mm/s (pitch = 1).

Computed tomographic images were initially interpreted by the in-house radiology resident and reviewed by a trauma radiologist. The result of each scan was recorded in detail and summarized as positive (CT+) or negative (CT−). CT was defined as positive if an intra-abdominal injury was depicted regardless of lesion severity. Such injuries included any contusion or laceration of an intra- or retroperitoneal viscera and/or the presence of free intra- or retroperitoneal fluid. Non–trauma-related abnormality (i.e., cirrhosis with ascites) was not considered CT+. Because this study was mainly focused on abdominal visceral injuries, any isolated bone lesion (spinal or pelvic fracture) without associated soft-organ

injury was not considered to be a positive study. However, isolated pelvic or spinal fractures were recorded separately. Free intraperitoneal fluid that could be logically explained (prior diagnostic peritoneal lavage, ascites from cirrhosis) without evidence of traumatic injury was recorded as CT−. Scoring of spleen and liver injuries was performed using the American Association for the Surgery of Trauma adapted CT-based injury scale classification.[13,14] Major injuries were defined as lesions requiring surgery or embolization (SE) as well as splenic grade II (or higher) and liver grade III (or higher) injuries, because of their potential for massive delayed bleeding, even if the clinical follow-up was uneventful.

The Injury Severity Score (ISS), defined as the sum of the squares of the highest injuries in three different regions, graded according to the 1990 revision of the Abbreviated Injury Scale,[15] was retrospectively calculated for each patient. Chest and pelvic radiographic results were retrospectively recorded on the basis of the official radiologist interpretation. Clinical follow-up was based on medical and surgical records obtained for each patient up to the time of discharge.

Data Analysis

Database and Definition of Normal Reference Values

For all patients, each clinical criterion was coded as absent or normal (0), present or abnormal (1), or not evaluated (−). The minimal (or maximal) normal values for systolic blood pressure (> 100 mm Hg), diastolic blood pressure (> 60 mm Hg), pulse (< 100 beats/min), and respiratory rate (< 16 breaths/min) was used on the basis of practice by trauma surgeons at our institution. A GCS score of 15 or 14 was considered normal, and all values below 14 were considered abnormal. The normal or abnormal values for the laboratory data were defined according to the normal range in use in the laboratory in which the tests were performed. The values considered as normal were 36% and above for hematocrit, 10,000/mm^3 and below for WBC, 2.2 mmol/L and below for serum lactate, 50 IU/L and below for SGOT, and 125 IU/L and below for amylase. All indeterminate results for FAST were considered as missing results (−).

On the basis of the radiology report, a chest radiograph was considered abnormal if a fracture (spine, rib), pleural effusion, abnormal air distribution (pneumothorax, pneumomediastinum), or parenchymal opacity consistent with contusion was reported. Because almost all thoracic radiographs were obtained with the patient in the supine position, an isolated enlarged (wide) mediastinum was considered normal in the absence of any other signs of mediastinal hemorrhage such as obscuration of the aortic contour, tracheal deviation to the right, and so forth.[16] Similarly, a pelvic radiograph was considered abnormal if an acute fracture (pelvis, spine) was diagnosed. Every nontraumatic incidental finding depicted by thoracic or pelvic radiography or CT, in the absence of any associated traumatic injury, was recorded separately but did not prevent the examination from being considered as negative regarding trauma.

Statistical Analysis

The data collected for each clinical, laboratory, radiographic, and sonographic study obtained before abdominal CT was evaluated to determine their ability to distinguish CT+ from CT− patients. Binary data were described as the number of negative, positive, and missing results according to diagnosis (CT, major injuries, SE). Sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) were calculated with CT as diagnosis. For continuous data, such as laboratory variables, receiver operating characteristic (ROC) curves were generated. Two different scores were arbitrarily defined to have the minimum number of patients with indeterminate results: clinical score (guarding, tenderness, and GCS score) and radiology score (FAST examination and chest radiograph). The scores were considered as pathologic as soon as one item was pathologic, normal if all the items were normal, and indeterminate of one or more items were missing but the others were normal.

Stepwise logistic regression was carried out using laboratory variables (SGOT, WBC, HCT, lactate, and amylase, all log-transformed except for HCT) to select a combination of variables best able to discriminate between abdominal-pelvic CT+ and CT− patients. For the same reason as above, we defined similarly a laboratory score with the selected variables, with each variable being considered as normal or pathologic according to the normal reference value given above. Stepwise logistic regression was also used to select the best combination of laboratory variables and clinical and radiologic scores to predict CT results. No separate attempt was made to discriminate patients with major injuries or SE from all others because of the relatively small number of patients with major injury (n = 39) or needing surgery or embolization (n = 26).

RESULTS

Characteristics of the Patients

Nine hundred protocol forms were provided to the clinical physicians on a consecutive basis for patients coming to CT for abdominal-pelvic scanning after blunt trauma. One hundred eighty-six were later discarded because of missing or unavailable key demographic data or results, or because patients were hemodynamically unstable and underwent immediate surgical exploration without CT. Seven hundred fourteen patients were included in the study. The study population consisted of 483 men and 231 women, with a mean age of 38.8 years (range, 13–97 years). Admission injury mechanism included motor vehicle collision in 430 cases (60.2%), falls in 125 (17.5%), assaults in 51 (7.2%), pedestrian struck in 51 (7.2%), motorcycle-related trauma in 17 (2.4%), and miscellaneous causes in the remaining 40 (5.5%) patients. Among this study population were 85 (12%) patients with CT results that were considered positive for an intra-abdominal injury, according to the definition described above, and 629 (88%) that were negative. CT was considered negative in five patients with a small amount of free intraperitoneal fluid

Table 1 Injured Organs and Severity Criteria of 85 Patients with Abnormal CT

	No. (% of CT+ Patients) (%)	Major Injury*	Main Reason for Surgery or Embolization
Spleen	46 (54)	22	16
Liver	26 (31)	11	4
Kidney	11 (13)		
Mesentery	9 (11)	1	1
Small bowel	8 (9)	2	2
Colon	3 (4)	2	2
Pancreas	2 (2)		
Bladder	2 (2)		
Adrenal	1 (1)		
Diaphragm	1 (1)		
Free fluid (hemoperitoneum)	57 (67)		
Total of injured organs	163	39	26

* Lesions requiring surgery or embolization as well as splenic grade II (or higher) and liver grade III (or higher), using the AAST injury scale and an AAST adapted CT-based classification, respectively ([13,14]). In columns 2 and 3, no more than one organ injury (the most severe) is reported per patient.

AAST, American Association for the Surgery of Trauma.

attributed to a nontraumatic origin. Two patients had a prior diagnostic peritoneal lavage, one had a known history of cirrhosis with ascites, and two women were in the middle of their menstrual cycle. There were 72 patients who had either a vertebral fracture (n = 25) from the levels of T12 to L5 or a pelvic fracture (n = 50). Three patients had fractures in both regions. Sixty-one of these 72 patients (85%) had no other associated traumatic intra-abdominal soft-tissue injury depicted by CT, which was therefore considered negative. Of the 85 CT+ patients, 39 had major injuries and 26 required surgery or angiographic embolization. Table 1 depicts the CT findings in the group of patients with an abnormal scan, as well as those with major injury and those who underwent surgery or embolization.

The average ISS was 11 (median, 9) in the total group of patients, 20 (median, 20) in the group of patients with a positive scan, and 10 (median, 9) in the group with a negative scan. The mean ISS among the patients with a normal scan but with a vertebral or pelvic fracture was 15 (median, 17).

The admitting physician's prediction of the abdominopelvic CT result was provided for 645 patients. The ROC curve for the physician's prediction was similar to that of the best single predictive parameter (SGOT) but not better (Fig. 1). It was also close to the ROC curve of the ISS. For simplification, we considered a prediction score of 1 and 2 as no clinical evidence for an intra-abdominal injury (n = 443) and a prediction score of 3, 4, or 5 as suspicion of intra-abdominal injury (n = 202). When using this classification, the PPV and NPV of the physician's clinical impression were 25% (50 of 202) and 95% (419 of 443), respectively.

Statistical Analysis of Potentially Predictive Criteria

Univariate Analysis

Information on all clinical, radiologic, and laboratory variables are given in Tables 2 and 3. All clinical signs missed a high number of CT+ cases (from 43 for tenderness to 74 for distention), showing sensitivity between 5% (rebound) and 46% (tenderness). Rebound missed the majority of CT+ cases (72, including 20 SE). This clinical sign was considered useless and not retained in the overall clinical score. Distention also missed 74 CT+ cases, including 21 SE, and was also rejected. Furthermore, this sign lacked specificity (e.g., obesity, cirrhosis); however, for some patients it was the only positive sign noted, and these patients usually had a low GCS score. The clinical score, as defined in the Patients and Methods section, including GCS score, guarding, and tenderness, missed 27 CT+ patients (5 SE). The clinical score had 68% sensitivity, 55% specificity, 17% PPV, and 93% NPV. It could not be defined for only eight cases, including one SE.

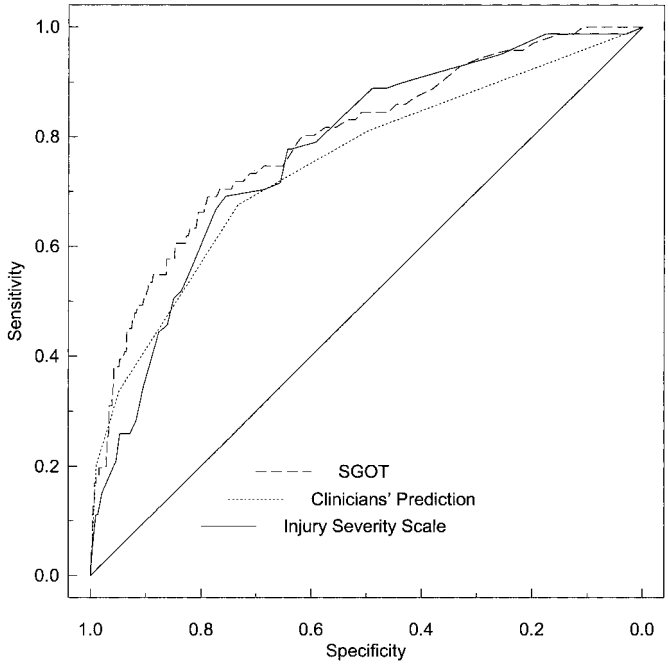

Fig. 1. *ROC curves for ISS and clinician's prediction. The characteristics are calculated for CT results.*

Table 2 Univariate and Multivariate Analysis*

Criteria	Negative Criteria				Positive Criteria				Indeterminate Criteria			
	–	Complication			+	Complication			XX	Complication		
		SE	MI	CT+		SE	MI	CT+		SE	MI	CT+
Clinical												
C: GCS score	598	17	27	62	116	9	12	23	0	0	0	0
G: Guarding	633	16	24	58	63	6	10	20	18	4	5	7
T: Tenderness	464	9	17	43	229	13	17	36	21	4	5	6
R: Rebound	685	20	31	72	9	1	2	4	20	5	6	9
D: Distention	673	21	33	74	32	5	6	11	9	0	0	0
Cl: C + G + T	370	5	11	27	336	20	27	57	8	1	1	1
Imaging												
F: FAST	456	8	15	42	32	14	14	18	226	4	10	25
P: Pelvis	667	24	36	76	45	2	3	8	2	0	0	1
Cx: Chest x-ray	569	16	21	49	139	10	18	35	6	0	0	1
xR: F + Cx	372	5	9	25	163	18	26	46	179	3	4	14
Laboratory												
S: SGOT	417	5	5	19	221	16	26	52	76	5	8	14
W: WBC	342	6	8	16	360	20	31	69	12	0	0	0
L: Lactate	267	3	4	20	373	20	31	55	74	3	4	10
H: HCT	576	12	23	53	136	13	15	31	2	1	1	1
SWH: S + W + H	212	3	3	5	472	22	34	78	30	1	2	2
Cl + xR	199	1	3	9	411	24	35	72	104	1	1	4
Cl + SWH	117	0	0	1	581	26	38	83	16	0	1	1
xR + SWH	129	0	0	1	498	25	38	82	87	1	1	2
Cl + xR + SWH	68	0	0	0	594	26	39	84	52	0	0	1

* Value of clinical, bedside radiologic, and laboratory criteria to predict an intra-abdominal injury as defined by CT results and need for surgery or angiographic embolization.

GCS, Glasgow Coma Scale; SE, need for surgery or angiographic embolization; MI, major injury; CT+, presence of an intra-abdominal injury by CT.

Table 3 Univariate and Multivariate Analysis*

Criteria	Level (%)	Sensitivity (%)	PPV (%)	Specificity (%)	NPV (%)	No. Missing
Clinical						
C: GCS score	16	27	20	85	90	0
G: Guarding	9	26	32	93	91	18
T: Tenderness	33	46	16	69	91	21
R: Rebound	1	5	44	99	89	20
D: Distention	5	13	34	97	89	9
Cl: C + G + T	48	68	17	55	93	8
Imaging						
F: FAST	7	30	56	97	91	226
P: Pelvis	6	10	18	94	89	2
Cx: Chest x-ray	20	42	25	83	91	6
xR: F + Cx	30	65	28	75	93	179
Labo						
S: SGOT	35	73	24	70	95	76
W: WBC	51	81	19	53	95	12
L: Lactate	58	73	15	44	93	74
H: HCT	19	37	23	83	91	2
SWH: S + W + H	69	94	17	34	98	30
Cl + xR	67	89	17	36	95	104
Cl + SWH	83	99	14	19	99	16
xR + SWH	79	99	16	24	99	87
Cl + xR + SWH	90	100	14	11	100	52

* Level (percentage of positive test), Sensitivity, Specificity, PPV, and NPV predictive values. The number of indeterminate cases is given in the last column.

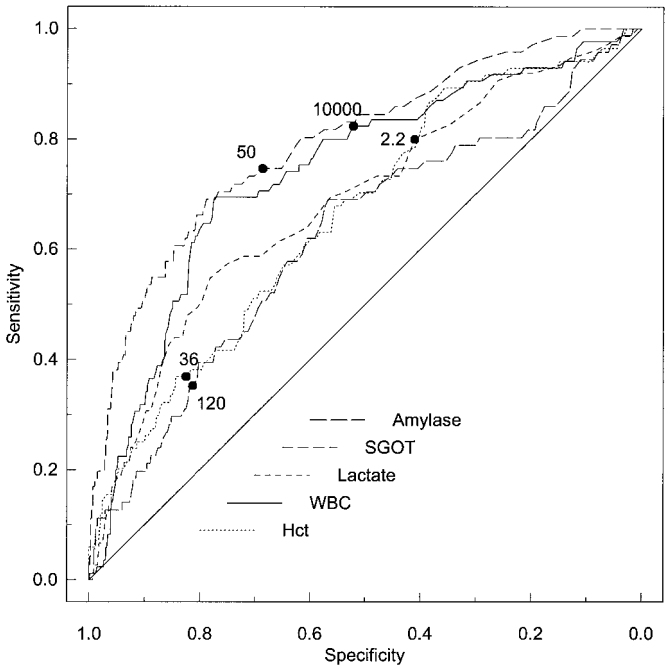

Fig. 2. *ROC curves for laboratory variables. The characteristics are calculated for CT results.*

Among imaging results, FAST and chest radiography missed 42 and 49 CT+ results, respectively, for a sensitivity of 30% and 42%, respectively. Pelvic radiography was considered useless because it missed 76 CT+ patients, including 24 SE. The radiologic score, including FAST and chest radiography, missed 25 CT+ patients (5 SE); unfortunately, 179 patients (14 CT+, 3 SE) could not be classified, primarily because of the lack of a FAST result with a normal chest radiograph. Plain radiography had 65% sensitivity, 75% specificity, 28% PPV, and 93% NPV.

Figure 2 depicts ROC curves for the laboratory variables. Using the chosen cutoff, laboratory data missed 53 CT+ patients for HCT, between 16 and 20 for SGOT, WBC, and lactate (Table 2). Sensitivity was 37% for HCT, 73% for WBC and lactate, and 81% for WBC (Table 3). Missing data were relatively frequent for SGOT (76, 14 CT+) and lactate (74, 10 CT+). The other variables (e.g., respiratory rate, blood pressure) are not shown, as their performance was very poor.

Multivariate Analysis

A stepwise logistic regression was carried out with five laboratory variables (SGOT, WBC, HCT, lactate, and amylase). In univariate analysis (first step), all five variables were highly significant ($p \leq 0.0001$), with SGOT being the most discriminant. Information on discrimination given by HCT is independent from the one given by SGOT ($p = 0.0001$, second step), as is the one given by WBC regarding the other two variables ($p = 0.002$, third step). Lactate and amylase did not add any more independent information. If the laboratory variables were considered as binary data, using the cutoff defined above, the same variables were chosen, but the performance was worse. These models were defined in 601 cases, including 69 CT+, without missing laboratory variables. The probability of CT+ increases with the amount of laboratory variables outside the normal range (Table 4). However, to retain as many cases as possible and to miss the fewest CT+, we have defined the laboratory score as normal if WBC, HCT, and SGOT all have normal values (472 patients) and pathologic if at least one is pathologic (212 patients). Only 30 patients could not be classified by this rule. Unfortunately, five CT+ patients (three SE) are still classified as normal by this criterion. This laboratory score had a sensitivity of 94%, a specificity of 34%, a PPV of 17%, and a NPV of 98%, having better sensitivity than the clinical or radiologic score.

Stepwise logistic regression with the three laboratory variables (as continuous variables), clinical scores, and radiologic scores was performed. In univariate analysis, all these variables were highly significant ($p = 0.004$ for clinical score and $p \leq 0.0001$ for all others). SGOT was the most significant. WBC was the next chosen variable ($p < 0.0001$), followed by HCT ($p = 0.01$). Clinical and radiologic scores are no more significant ($p = 0.07$). With binary laboratory data, SGOT was again the most significant ($p < 0.0001$), followed by the radiologic score ($p < 0.0001$) and WBC ($p = 0.002$). Clinical score was marginally significant ($p = 0.03$). HCT added marginally insignificant information ($p = 0.051$).

The combination of clinical and radiologic scores had a performance similar to the laboratory score, but with more indeterminate cases (104 vs. 30) (Table 3). The sensitivity was 89% and 94%, respectively, with specificity of 36% and 34%, PPV of 17% and 17%, and NPV of 95% and 98%, respectively. The performance of a combination of two systems including the laboratory score allows a greater sensitivity (99%) with a reasonable specificity (19% with clinical score and 24% with radiologic score), a low PPV (14% with clinical score and 16% with radiologic score), and a high NPV (99%) (Table 3). Indeterminate cases were 16 for clinical and laboratory scores but 87 for radiologic and laboratory scores. Combining all three systems allowed the classification of all CT+ cases as pathologic, but only 68 cases were classified as normal and 52 (1 CT+) could not be classified (sensitivity and PPV of 100%, but specificity of only 11% and PPV of only 14%).

Table 4 gives the number of CT+ cases, major injuries, and surgery or embolization procedures according to the clinician's score and the number of positive items in different scores including SWH (laboratory values). There is a net increase of CT+ with an increasing number of positive items, from 2% to 44% for SWH. The 69 patients with at least 1 positive item but some missing item(s) have an intermediate result (24%). Combining clinical or radiologic results and SWH adds more discrimination. All three together give more or less identical results for adjacent lines (zero and one, two,

Table 4 Proportion of CT+ Regarding the Amount of Positive Items*

Criteria	Number+	Total	SE	MI	CT+	% CT+
Clinician's prediction (score)	1	298	1	4	14	5
	2	145	0	4	10	7
	3	147	3	7	25	17
	4	34	7	7	10	29
	5	21	11	12	15	71
	XX	69	4	5	11	16
SWH	0	212	3	3	5	2
	1	229	2	3	13	6
	2	153	7	14	35	23
	3	41	9	11	18	44
	1+	49	4	6	12	24
CI + SWH	0	117	0	0	1	1
	1	223	4	4	6	3
	2	154	3	6	26	17
	3	89	3	8	18	20
	4+	27	8	9	14	52
	1+	88	8	11	19	22
xR + SWH	0	129	0	0	1	1
	1	157	5	6	10	6
	2	94	1	4	18	19
	3	74	7	10	20	27
	4	23	8	10	14	61
	1+	150	4	8	20	13
CI + xR + SWH	0	68	0	0	0	0
	1	150	1	1	2	1
	2	103	4	7	18	17
	3	79	2	2	13	16
	4	42	4	9	15	36
	5+	16	7	7	9	56
	1+	204	8	13	27	13

* Correlation between the amount of abnormal items within a combined criteria regarding positive abdominal CT.

Keys are the same as in Table 2. Patients without clinician's prediction are listed as XX. Cases with missing items, but at least one positive, are listed as 1+. MI can only be ruled out when there is a zero in column MI.

and three positive items). This is the only combination that is able to exclude an intra-abdominal injury when clinical, bedside radiologic analysis, and the three laboratory data are normal. However, only 12% (68 of 578) of CT− patients fulfilled these criteria.

DISCUSSION

In the current series, the authors analyzed the value of admission clinical examination, bedside radiologic investigations, and laboratory data to predict the presence of an intra-abdominal injury as determined by CT results. Because the management of patients is related to the severity of the injury, differentiation was made between minor injuries that do not require any treatment and major injuries that are potentially lethal. Prior studies suggest that patients with even low-grade spleen or liver injuries are at risk for delayed massive bleeding.[17,18] However, these series usually do not make a distinction between grade I and grade II splenic and grade I to III liver injuries, all of them being considered "low grade." Recent surveys[19–21] show that the risk of complications is correlated with the grade of the injury and is very unusual in grade I splenic laceration and in liver injuries below grade III. On the basis of these observations, we did consider as "major" any abdominal-pelvic injury requiring surgery or embolization, as well as all spleen laceration of grade II and higher and liver lacerations of grade III and higher. All other injuries were arbitrarily considered minor, because they do not carry a high risk of massive bleeding and fatal outcome.

Clinical Examination

The sensitivity of the clinical examination for detection of an intra-abdominal injury is difficult to assess because it depends on the definition of a normal clinical examination and the reference standard study chosen. To our knowledge, no prior study directly compares the result of clinical examination with CT scan exclusively. In the current series, the abdominal clinical examination consisted of four major signs (tenderness, rebound, guarding, and distention) and the GCS score that are routinely recorded by the admitting physician in our institution. Tenderness and guarding were somewhat sensitive for indicating an intra-abdominal injury, whereas distention and rebound were not (Table 3). When abdominal tenderness, guarding, and GCS score ($\leq$13 vs. $\geq$14) were combined, sensitivity was 68% (57 of 84) and specificity was 55% (343 of 622). Our results are close to those reported in different studies.[7,13,18,22]

Interestingly, the clinician's overall subjective impression ROC curve with regard to the presence of an abdominal injury was very similar to that of ISS and not better than that of a single item like SGOT. The clinician is probably mainly influenced and perhaps misguided by the presence of extra-abdominal "distracting injuries" to predict the occurrence of an intra-abdominal injury. The presence of an extra-abdominal injury (distracting injury) has been shown to increase the number of false-negative clinical examinations for intra-abdominal injury, when compared with the result of CT.[4] This observation could explain the fact that in this series the mean ISS in the group of patients with a GCS score $>$ 13 was higher when the clinical examination was false-negative than when it was true-positive. Of course, the clinical skills of different examining physicians can vary, so these results apply only to an aggregate of various training levels as represented at our trauma center.

Laboratory Data

Statistical analysis of all recorded laboratory values suggested that SGOT and WBC were the most sensitive and specific data with which to predict abdominal injury after blunt trauma. A low HCT ($<$36%) is less sensitive to the presence of abdominal injuries but so often associated with major injuries that it compels the clinician to order further investigations. These three blood test results are readily available within 1 hour after admission in most emergency facilities and can therefore easily be used as a screening test for blunt abdominal trauma. Recent research reports that a large variety of inflammatory markers (interleukin-6, tumor necrosis factor, prostaglandin F, C-reactive protein, lactate, WBC, and others) are elevated in the severely injured patient.[23–26] The peak plasma concentration of these markers has been noted to occur within the first hours after trauma.[23–26] Early activation of the inflammatory system has been correlated with the development of multiple organ failure or the ISS.[24,27] In an attempt to better understand the mechanism for multiple organ failure after an injury, Botha et al.[25] analyzed the fluctuation of WBC over the first 24 hours after injury. At admission, the WBC was elevated because of an absolute lymphocytosis. Three hours after injury, the WBC peaked at 13,900 $\pm$ 1,400 and remained above 10,000 for approximately 2 more hours, the polymorphonuclear neutrophils being at this time the predominant circulating leukocytes.

SGOT was the first laboratory value to be found in association with CT+ cases in the statistical analysis. SGOT is widely distributed in different tissues including the liver, heart, kidney, pancreas, and muscles.[28] The value of an elevated SGOT to predict an intra-abdominal injury has already been reported.[10]

Some studies suggested that the value of blood lactate is a prognostic index of mortality or morbidity and is a good predictor of the severity of the injury.[29] However, the exact meaning of an increased level of serum lactate remains unclear.[30] In the current study, the blood lactate level did not add further information to the combination of WBC, SGOT, and HCT with regard to CT results.

It has been shown that serum amylase and lipase are randomly elevated in the initial evaluation of patients with blunt abdominal trauma who do not have pancreatic injury, but there is no identifiable subgroup of patients in which these parameters are consistently elevated.[31] Other authors[32] have reported that determination of the serum amylase level is not diagnostic of blunt injury within 3 hours or less after trauma, irrespective of the type of injury. Therefore, the initial amylase level after admission could not be helpful in immediate diagnostic management. In the current study, the blood amylase level was significantly higher in the group of patients in whom an abdominal injury was demonstrated by CT, compared with patients without injury, but did not improve the total sensitivity and specificity to predict an intra-abdominal injury when added to SGOT, WBC, and HCT in a logistic regression analysis.

Bedside Radiographic Examinations

The potential for false-negative ultrasound results for abdominal organ injury, even when performed by well-trained personnel, has been reported.[9,33] In the current study, the sensitivity of FAST, performed by a member of the admitting team, to detect an intraperitoneal organ injury in blunt abdominal trauma victims was relatively low. Other series[6,8,9] report a higher sensitivity of ultrasound to demonstrate intraperitoneal free fluid. However, in these series, ultrasound results were generally performed and repeated by the same well-trained operators, reviewed in a second step by a radiologist, and compared with clinical follow-up. Because not all patients underwent a CT examination, the exact prevalence of patients with potentially major injuries who had a false-negative ultrasound examination, despite an uneventful clinical follow-up, cannot be precisely estimated. Our results concern the initial result of FAST at a Level I trauma center, performed by different nonradiologist operators, without delayed review by a radiologist, and were compared with CT results. Our results probably more closely reflect the casual use of abdominal ultrasound in a busy emergency room.

The association of lower rib fractures and multiple rib fractures with liver and spleen injury is well known.[34] Our data suggest that a patient with an abnormal chest radiograph should also be investigated for abdominal injury. The absence of thoracic injury by radiography does diminish the risk of concomitant severe abdominal trauma.

Algorithms for Selecting Blunt Abdominal Trauma Patients for CT or Abdominal Clinical Observation

The current study suggests that there is no specific combination of admission clinical, radiologic, or laboratory parameters with which to exclude an intra-abdominal visceral injury for a majority of blunt trauma patients without performing CT. The clinician's personal impression has too many false-negative results with regard to the presence of

minor (5.4% [24 of 443]) and major (1.8% [8 of 443]) intra-abdominal injuries to be relied on for the decision not perform further investigations. A normal clinical examination (no abdominal tenderness and no guarding at palpation) along with normal bedside radiologic results (FAST and chest radiographs) in a patient with a GCS score > 13 would still miss 11% (9 of 81) of abdominal injuries, 33% of them (3 of 9) being considered major.

The best algorithm for excluding a major injury in the largest number of patients in our series was obtained when both pre-CT radiologic analysis and laboratory data were normal. Under these conditions, 22% (129 of 589) of patients without major injuries could be recognized. This algorithm missed 1 (1.2%) minor intra-abdominal injury among 83 CT+ patients meeting the criteria.

Finally, the combination of normal abdominal palpation (no tenderness or guarding), normal bedside imaging examination (FAST and chest radiograph), and normal laboratory data (HCT, WBC, and SGOT) was found to be the only combination able to exclude an intra-abdominal injury in an alert patient. However, this combination of negative results is found in only 11% (68 of 611) of our CT− patients.

There are some limitations in the current series that must be discussed. First, only patients already selected to undergo CT were enrolled. The decision not to perform CT in a certain number of patients was made on the basis of criteria that could not be analyzed. However, because most of the patients with suspicion of blunt abdominal trauma undergo abdominal CT in our institution, this limitation only concerns a very small number of cases and should probably not contribute any consistent bias to the results. Such liberal use of CT scanning explains the high rate of negative abdominal CT examinations (88%) at our institution. Second, the fact that not all patients had data forms completed may also have led to an unmeasured selection bias. However, because different teams of different surgeons did fill out the forms, this bias appears to be a random outcome with probably limited, if any, consequences to the final results. Third, a substantial amount of data were not available (e.g., indeterminate or not performed examinations, missing data), because a standardized protocol cannot always be straightforwardly applied in all emergent situations. Nevertheless, because all individual items must be negative to consider an algorithm normal and at least one must be positive to consider it abnormal, these missing data only affect a small percentage of combinations that could not be considered for further statistical analysis (7% [52 of 714], when all criteria were considered). The total effect of the missing data on the overall results should therefore be limited.

CONCLUSION

The statistical analysis of combined admission bedside clinical, sonographic, radiologic, and laboratory results obtained in this survey defines some algorithms that can be helpful for selecting a group of patients with suspected blunt abdominal trauma who do not require subsequent abdominal investigation (CT or clinical follow-up). However, because of the lack of specificity of non-CT parameters, only a relatively small percentage of CT− patients (11% [68 of 611]) can be considered free of intra-abdominal injuries by this method. Less selective criteria can be used to select patients for the presence of a life-threatening injury only but will miss some minor injuries. At best, in the current series, 22% (129 of 589) of patients without major injury could have been discharged without further investigation. The majority of patients with suspicion of blunt abdominal trauma should therefore undergo extended clinical observation or abdominal CT.

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