Use of abdominal computed tomography in blunt trauma: Do we scan too much?

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OBJECTIVES: To determine what proportion of abdominal computed tomography (CT) scans ordered after blunt trauma are positive and the applicability and accuracy of existing clinical prediction rules for obtaining a CT scan of the abdomen in this setting.

SETTING: A leading trauma hospital, affiliated with the University of Ottawa.

DESIGN: A retrospective cohort study.

PATIENTS AND METHODS: All patients with blunt trauma admitted to hospital over a 1-year period having an Injury Severity Score (ISS) greater than 12 who underwent CT of the abdomen during the initial assessment. Recorded data included age, sex, Glasgow Coma Scale (GCS) score, ISS, type of injuries, number of abdominal CT scans ordered, and scan results. Two clinical prediction rules were found in the literature that identify patients likely to have intra-abdominal injuries. These rules were applied retrospectively to the cohort. The predicted proportion of positive CT scans was compared with the observed proportion, and the sensitivity, specificity, and accuracy were estimated.

RESULTS: Of the 297 patients entered in the study, 109 underwent abdominal CT. The median age was 32 years, 71% were male and the median ISS was 24. In only 36.7% (40 of 109) of scans were findings suggestive of intra-abdominal injuries. Application of one of the clinical prediction rules gave a sensitivity of 93.8% and specificity of 25.5% but excluded 23% of patients because of a GCS score less than 11. The second prediction rule tested could be applied to all patients and was highly sensitive (92.5%) and specific (100.0%).

CONCLUSIONS: The assessment of the abdomen in blunt trauma remains a challenge. Accuracy in predicting positive scans in equivocal cases is poor. Retrospective application of an existing clinical prediction rule was found to be highly accurate in identifying patients with positive CT findings. Prospective use of such a rule could reduce the number of CT scans ordered without missing significant injuries.

OBJECTIFS : Déterminer la proportion des tomographies abdominales commandées après un traumatisme contondant qui donnent des résultats positifs, ainsi que l'applicabilité et l'exactitude des règles actuelles de prévision clinique à suivre pour obtenir une tomographie de l'abdomen dans ce contexte.

CONTEXTE : Grand hôpital de traumatologie affilié à l'Université d'Ottawa.

CONCEPTION : Étude de cohorte rétrospective.

PATIENTS ET MÉTHODES : Tous les patients victimes d'un traumatisme contondant hospitalisés en un an et présentant un indice de gravité des traumatismes (IGT) de plus de 12 qui ont subi une tomographie de l'abdomen pendant l'évaluation initiale. Les données consignées portaient notamment sur les aspects suivants : âge, sexe, score sur l'échelle de Glasgow (SEG), IGT, type de lésions, nombre de tomographies abdominales commandées et résultats. On a trouvé dans les écrits deux règles de prédiction clinique permettant d'identifier les patients qui ont probablement subi des lésions intra-abdominales. Ces règles ont été appliquées de façon rétrospective à la cohorte. On a comparé la proportion prévue de tomographies donnant des résultats positifs à la proportion observée, et estimé la sensibilité, la spécificité et l'exactitude de l'examen.

RÉSULTATS : Sur les 297 patients inscrits à l'étude, 109 ont subi une tomographie abdominale. Leur âge médian était de 32 ans, 71 % étaient de sexe masculin et l'IGT médian s'établissait à 24. Dans 36,7 % (40 sur 109) seulement des tomographies, les résultats indiquaient la présence de lésions intra-abdominales. L'appli-

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cation d'une des règles de prévision clinique a donné une sensibilité de 93,8 % et une spécificité de 25,5 %, mais elle a exclu 23 % des patients parce que leur SEG était de moins de 11. La deuxième règle de prévision a pu être appliquée à tous les patients et s'est révélée très sensible (92,5 %) et spécifique (100,0 %).

CONCLUSIONS : L'évaluation de l'abdomen dans les cas de traumatisme contondant pose toujours un défi. La prévision de résultats positifs d'une tomographie dans des cas équivoques est d'une exactitude médiocre. On a constaté que l'application rétrospective d'une règle existante de prévision clinique est très exacte lorsqu'il s'agit de déterminer les patients chez lesquels la tomographie donnera un résultat positif. L'application prospective d'une telle règle peut réduire le nombre de tomographies commandées sans omettre des lésions importantes.

The diagnosis of intra-abdominal injury after blunt trauma remains a challenge. A combination of clinical examination and ancillary diagnostic tests, such as diagnostic peritoneal lavage (DPL),[1–3] computed tomography (CT) of the abdomen[4–7] and, most recently, focussed abdominal ultrasonography[8–13] for free intraperitoneal fluid have been used.

There are numerous reports that the accuracy of abdominal CT is comparable to that of DPL for most injuries, and CT has the advantage of providing more information on the nature and extent of the injuries, as well as identifying retroperitoneal hematomas.[14–17] However, abdominal CT is an expensive, time-consuming investigation frequently performed late at night during the precious golden hour of trauma resuscitation and evaluation.[18,19] Inappropriate use may delay the performance of other important interventions or investigations. Alternatively, missing a significant intra-abdominal injury could lead to disastrous consequences.

Selection of patients for ancillary diagnostic tests of the abdomen after blunt trauma becomes a crucial management decision in the early post-traumatic period. There is lack of information in the literature defining a strategy to select the patient at high risk of intra-abdominal injury who requires adjunctive diagnostic tests. Criteria advocated by the American College of Surgeons[20] are largely empiric and not based on solid evidence. A review of the literature reveals two studies that attempted to identify a high-risk group. The first by Mackersie and colleagues[21] reported that the presence of arterial base deficit, major chest injury, hypotension and pelvic fractures were significantly associated with intra-abdominal injury. The second study by Grieshop and associates[22] found that an abnormal abdominal examination or the presence of chest injury or gross hematuria was highly predictive. Neither of these clinical prediction rules has ever been validated in an independent population to determine their clinical accuracy.

The purpose of this study was to evaluate our usage pattern for abdominal CT in blunt trauma and to validate existing clinical prediction rules in our blunt trauma population.

Methods

All blunt trauma admissions to The Ottawa Hospital – General Site (formerly the Ottawa General Hospital) between July 1, 1995, and July 1, 1996, formed the study population. This hospital is the lead trauma centre for the Ottawa-Carleton area of eastern Ontario and serves part of western Quebec. On average, 240 trauma patients having an Injury Severity Score (ISS)[23] greater than 15 are admitted annually. Data on all trauma admissions were collected prospectively by trained data analysts who tracked each patient until discharge. All charts were independently adjudicated to confirm the accuracy of registry data. Patients in whom an abdominal injury was suspected or in whom such an injury could not be excluded on physical examination alone underwent either CT of the abdomen or DPL. All abdominal CT was performed with use of conventional techniques.

Data collected for analysis included age, sex, anatomic injury classification, ISS, Revised Trauma Score (RTS),[24] Glasgow Coma Scale (GCS) score,[25] systolic blood pressure, respiratory rate, hemoglobin level, blood alcohol level and the presence of arterial blood-gas base deficit. All physiologic variables were those recorded on arrival in the Emergency Department. The results of the physical examination of the abdomen, including the presence of tenderness, abdominal distension and bruising as documented in the chart, was also recorded. The total number of abdominal CT scans ordered on initial assessment was documented, and the proportion of scans that were positive was recorded. A positive scan was defined, on the basis of the radiology report, as exhibiting any intra-abdominal abnormality, including pneumoperitoneum, retroperitoneal hematomas and leakage of gastrointestinal contrast fluid. Finally, missed injuries were defined as any intra-abdominal injury undetected after initial trauma assessment that subsequently resulted in morbidity or mortality.

Subsequent analysis was performed on all patients who underwent CT of the abdomen. A descriptive analysis was performed on all variables. Univariate analysis compared those with positive and negative CT scans of the abdomen. Two existing clinical prediction rules (Table I) were then applied to the data, and the predicted CT result was compared with that reported in the chart. The predictive ability of the rules was evaluated by calculating the sensitivity, specificity and accuracy.

All continuous variables were analysed by parametric procedures (Student's *t*-test) or nonparametric procedures (Mann–Whitney U test). Unless otherwise stated, all values are given as means (and interquartile ranges). Categoric variables were analysed by unadjusted χ^2 tests. Absolute *p* values and 95% confidence intervals are reported where appropriate, and no corrections were made for multiple comparisons.

Results

Of 297 blunt trauma patients identified over the study period, 109 (36.7%) underwent abdominal CT (Fig. 1). The CT scan was positive for 40 patients (36.7% of CT scans obtained) of whom 13 (12% of study cohort) underwent laparotomy. Of the 188 patients who did not undergo CT of the abdomen, 17 had a laparotomy, 8 of them because of a positive DPL and 9 because the physical examination revealed evidence of a "surgical abdomen."

Those patients who underwent abdominal CT had a median age of 32 years (interquartile range 19 years), 71% were male, the median ISS was 24 (interquartile range 13), the median abdominal Abbreviated Injury Score was 2.0 and the all-cause in-hospital death rate was 4.6% (Table II). The commonest injuries were to the thorax (44%) followed by central nervous system injuries (39%), pelvic fractures (16%), long bone fractures (19%) and multiple injuries in 10% (Table III). On physical examination tenderness was noted in 53% of patients, distension in 34% and bruising in 42% (Table IV).

A CT diagnosis of intra-abdominal injury was made on the basis of multiple findings on any given scan, including the identification of the following: solid organ injury (77.5%), hemoperitoneum (21%), retroperitoneal hematoma (17.5%) mesenteric hematoma (5.0%) and pneumoperitoneum (5.0%) Leakage of gastrointestinal contrast medium was not noted. Univariate analysis revealed that patients with positive scans were younger (28 v. 35 years, $p = 0.003$ [Table II], had a lower mean hemoglobin level (120 v. 135 g/L, $p = 0.018$ [Table II]), with more abdominal tenderness (74% v. 40%, $p = 0.002$ [Table IV]) and abdominal distension (52% v. 23%, $p = 0.039$ [Table IV]). Patients with positive CT scans also had a higher frequency of pelvic fractures (30% v. 15.4% [Table III]) and gross hematuria (17.6% v. 8% [Table II]) although these results were not significant. There were no documented cases of a subsequent missed injury in patients with a negative CT scan.

Performance characteristics of the clinical prediction rules are summarized in Table V. Application of Grieshop's rule excluded 23.8% (26 of 109) of patients because of a GCS score less than 11. This rule showed a sensitivity of 93.8%, a specificity of 25.5% and overall accuracy of 51.8%. In contrast, Mackersie's rule demonstrated a sensitivity of 92.5%, a specificity of 100.0% and an overall accuracy of 97.2%. Mackersie and colleagues's rule could be applied to all patients regardless of their level of consciousness.

Table I

Clinical Prediction Rules for the Use of Abdominal Computed Tomography in Trauma

Rule	Description
Grieshop et al[22] (applicable to patients with a Glasgow Coma Scale score > 10)	Abnormal physical examination; or 1 or more of the following risk factors:
	Chest injury (any Abbreviated Injury Score grade)
	Gross hematuria
Mackersie et al[21] Presence of 1 or more of the following:	Arterial base deficit > 3 mmol/L
	Major chest injury (multiple fractured ribs, fractured sternum, flail chest, fractured scapula, crushed chest)
	Hypotension (systolic blood pressure < 90 mm Hg)
	Pelvic fracture

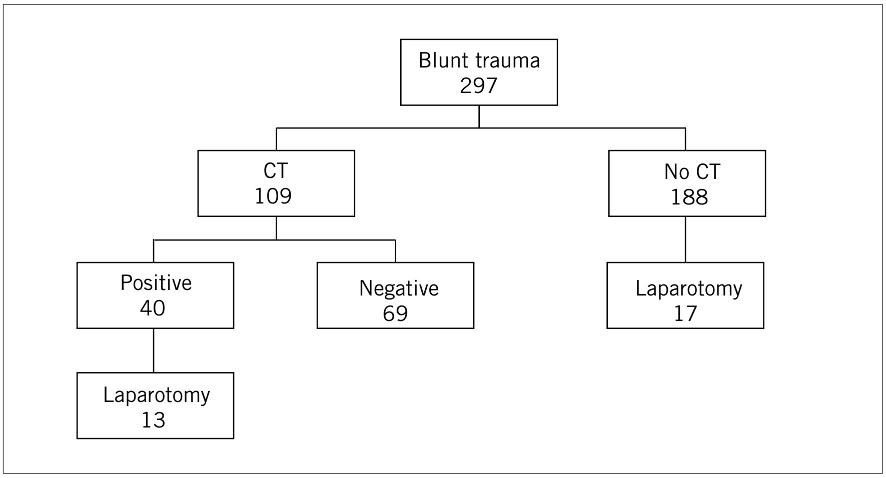

FIG. 1. Details of the 297 patients with blunt trauma identified over the study period.

Discussion

The purpose of this study was to evaluate our selection criteria for the use of abdominal CT in patients who were clinically deemed at risk of abdominal injury after blunt trauma. We found that the accuracy of these criteria in predicting positive scans was poor because only 36.7% of scans ordered revealed any evidence of injury. Use of the clinical prediction rule described by Mackersie and colleagues[21] demonstrated an accuracy of 97.2% and could be applied to all blunt trauma cases in contrast to the other rule tested. Application of such a rule could potentially expedite the time taken to investigate blunt trauma victims without the risk of missing important injuries.

Missed injuries, the nemesis of all trauma specialists,[26] include any intra-abdominal injuries not detected at initial assessment that subsequently lead to morbidity or mortality. Although these have typically consisted of hollow viscus, retroperitoneal and diaphragmatic injuries they also include missed solid organ injuries, which continue to bleed.[26] The evaluation of blunt abdominal trauma can be particularly challenging since physical examination alone has a sensitivity of only 50% to 60% for the detection of injuries.[19] Consequently, ancillary tests such as DPL and CT of the abdomen are an integral part of our diagnostic arsenal. DPL has been the standard for some time because of the ease and rapidity with which it can be performed as well as its accuracy of up to 98% in detecting intraperitoneal blood.[1–3] The difficulty with DPL is that it is frequently "too sensitive" for intraperitoneal blood often leading to nontherapeutic laparotomy and is poor at characterizing the severity of organ injury.[16,17,19] The latter is of key importance given the growing trend of trauma surgeons to manage solid organ injuries nonoperatively when feasible.[27] CT of the abdomen has been established as a sensitive means of identifying intraperitoneal blood, detecting retroperitoneal hematomas and characterizing the magnitude of solid organ injuries.[4–7,14–17,19] The disadvantages are that CT is insensitive for detecting hollow viscus injury and requires the administration of oral contrast material, the use of which is time consuming and places the patient at risk of aspiration.[18,19] Abdominal CT has largely been used to evaluate hemodynamically stable patients whereas DPL has traditionally been reserved for those with hemodynamic instability.[16] Nevertheless, the 2

Table II

Characteristics of Patients Who Had Positive and Negative Computed Tomography Scans

Characteristic	Patients, All	Patients, Positive	Patients, Negative	*p* value
Age, yr, median (IQR)	32 (19)	28 (19)	35 (28)	0.003
Sex, % male	71.0	72.1	70.0	NS
ISS, median (IQR)	24 (13)	28 (15)	22 (12)	0.001
RTS, median (IQR)	7.8 (0.3)	7.8 (0)	7.8 (0.9)	NS
GCS score, median (IQR)	15 (2)	15 (2)	15 (1)	NS
Mortality, % of patients	4.6	2.6	7.5	NS
Hemoglobin, g/L (IQR)	130 (31)	120 (30)	135 (30)	0.018
Gross hematuria, % of patients	11.9	17.6	8.0	NS
Blood alcohol (what measurement) median (IQR)	4.0 (26.3)	2.0 (27.0)	6.0 (26.0)	NS
Arterial base deficit, mmol/L, median (IQR)	3.5 (4.3)	4.1 (5.1)	3.1 (3.2)	NS

IQR = interquartile range, ISS = Injury Severity Score, RTS = Revised Trauma Score, GCS = Glasgow Coma Scale.

Table III

Injuries Sustained by Patients With Blunt Trauma Who Underwent Computed Tomography for Diagnosis

Injury	Patients, %: All	Scan positive	Scan negative
Multiple injuries	10	15.8	12.9
Long bone fracture	19	20.5	18.5
Pelvic fracture	16	30	15.4
Spinal injury	7	7.5	9.2
Thoracic injury	44	52.5	45.3
Central nervous system injury	39	40	46.7

Table IV

Physical Signs in Patients With Blunt Trauma Who Underwent Computed Tomography

Sign	Patients, %: All	Scan positive	Scan negative	*p* value
Tenderness	53	74	40	0.002
Distension	34	52	23	0.039
Bruising	42	47	38	NS

procedures are not mutually exclusive, and DPL has been advocated as a means of detecting small-bowel injury after an equivocal abdominal CT since neither test alone is entirely accurate in excluding this diagnosis.[16]

The decision to use ancillary tests for detecting abdominal injuries in blunt trauma is a critical step in the evaluation process. The American College of Surgeons Advanced Trauma Life Support course recommends the use of ancillary diagnostic techniques if the abdominal examination is equivocal due to associated distracting injuries such as rib fractures or fractured pelvis, or unreliable due to head injuries, presence of intoxicants or spinal cord injury.[20] In our institution, selection of patients for further assessment of abdominal injuries is based on these recommendations. However, use of these criteria were inaccurate because only 36.7% of scans showed evidence of intra-abdominal injury and only 13 (12%) of these patients required a laparotomy. We postulated that use of a more accurate clinical prediction rule may eliminate the need for such scans without detriment to the patients. This would save time and money during the early resuscitation and evaluation of our blunt trauma cases.

Two clinical prediction rules have been published that allow identification of patients at risk of intra-abdominal injury who require further diagnostic evaluation.[21,22] Neither of these had been validated at other institutions. The utility of such clinical prediction rules lie in their ability to reduce the uncertainty inherent in medical practice by defining how to use clinical findings to make predictions.[28] They have been successfully employed in a variety of settings, such as the need to obtain radiographs in ankle injuries,[29] and the evaluation of chest pain.[30] The usefulness of these rules depends largely on the use of appropriate methodology in their creation. These rules should be derived prospectively and should be independently validated. Appropriate statistical techniques such as recursive partitioning or logistic regression analysis should be employed to create them.[28] The final rule must be generalizable to all patients and be both highly specific (ability to rule in the condition) and sensitive (ability to rule out the condition). Although it is important for a clinical prediction rule of abdominal injuries to be both specific and sensitive, the latter is probably of greater importance. This is because a negative prediction of injury would require a rule with high sensitivity in order to be certain that an injury would not be missed.

Both of the rules evaluated in this study were prospectively derived and used logistic regression analysis to identify variables predictive of a positive CT scan. Blinded assessment of the clinical outcome and clinical predictor was not a feature of either study, raising possible introduction of investigator biases. The rule described by Grieshop and associates[22] excluded patients with a GCS less than 11. This group constituted 24% of our cohort and represents precisely those patients in whom physical examination alone cannot exclude abdominal injury. In contrast, the rule described by Mackersie and colleagues[21] was highly sensitive, specific and excluded no patients. Further studies applying the latter rule prospectively will help determine if it can safely limit the number of CT scans required to rule out abdominal injury without the dreaded consequence of missing an important diagnosis.

It may be argued that the use of a clinical prediction rule for abdominal CT in blunt trauma is limited owing to the growing adoption of focussed abdominal sonography in trauma (FAST).[8–13] This diagnostic technique has been shown to be as reliable as DPL in identifying intraperitoneal blood with the added advantage that it is rapid, requires no transport of the patient and is noninvasive. However, we believe that the learning curve necessary for diagnostic accuracy to be achieved with ultrasonography means that the standardized use of this in Canadian trauma centres is likely several years away and clinical prediction rules may still play a useful role in identifying patients at risk of intra-abdominal injuries who warrant further investigation.

In summary, we found that use of the American College of Surgeons guidelines were not accurate for selecting patients at risk of intra-abdominal injuries. Use of Mackersie's clinical prediction rule applied retrospectively markedly improved this, with a sensitivity of 92.5% and an overall accuracy of 97.2%. This rule could be applied to patients in whom physical examination alone would be incapable of excluding abdominal injury because of derangement in their level of consciousness. While many have advocated ultrasonography as the screening tool of choice, this technique is unlikely to replace CT, and its use in Canadian trauma centres is likely several years away. Optimally, further refinement of clinical prediction rules can be developed in parallel to the use of ultrasonography since many centres will also perform CT on their patients during

Table V

Performance Characteristics of the Clinical Prediction Rules for Identifying Patients With Intra-abdominal Injuries

	Rule, % (95% confidence interval)	
Characteristic	Grieshop et al[22]	Mackersie et al[21]
Sensitivity	93.8 (79.2–99.2)	92.5 (79.6–98.4)
Specificity	25.5 (14.3–39.6)	100.0 (94.8–100.0)
Accuracy	51.8 (40.6–62.9)	97.2 (92.2–99.4)

the period in which traumatologists are learning to interpret sonograms. Ultimately, such a rule could be used to limit the use of any ancillary diagnostic techniques in ruling out abdominal injury. The benefits of streamlining investigations on multiple trauma patients using well-validated clinical prediction rules could be enormous.

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