Clinical predictors of intra-abdominal injury in severe blunt trauma patient
嚴重鈍性創傷病人的腹內受傷臨床預報因子

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Introduction: The early recognition of intra-abdominal injury (IAI) in patients with blunt trauma is essential, yet physical examination is often unreliable. Computed tomography (CT) scans are used widely to further evaluate possible IAI but these require time and expense. IAI may be associated with certain objective risk factors or other specific injuries, but this association has not been widely studied. Identification of such risk factors will help to prioritize patients in need for further evaluation of possible IAI. ***Methods:*** A retrospective chart review was conducted of all 622 adult severe blunt trauma patients (Injury Severity Score [ISS] >12) presenting to a level 1 trauma centre in 2004. Various clinical predictors of IAI were analyzed statistically with univariate and multivariate analysis using SAS software. ***Results:*** In multivariate analysis, four significant predictors of IAI were found: positive focused assessment with sonography for trauma (FAST) (OR=48.5, p<0.0001), presence of pelvic fracture (OR=2.4, p=0.0002), chest tube insertion (OR=1.8, p=0.0211), and systolic blood pressure (SBP), where every 10 mmHg decrease indicates a 14% increase in risk (OR=0.986, p=0.001). The absence of all four predictors predicted the absence of IAI with a specificity of 0.776 (95% CI 0.741 to 0.808) and a LR of 2.7 (95% CI 2.0 to 3.5). ***Conclusion:*** This study suggests that positive FAST, presence of pelvic fracture, chest tube insertion, and SBP are significant predictors of IAI in adult blunt trauma patients with ISS >12. The absence of all four predictors is associated with a reduced risk of IAI. *(Hong Kong j.emerg.med.* 2009;16:76-83)

導言：於鈍性創傷病人中，及早認出腹內受傷是必要的，但身體檢查經常是不可靠。電腦掃描被廣泛使用以進一步評估腹內受傷的可能，但需要時間及花費。腹內受傷可能與一些客觀的風險因素或其他特殊傷勢有關，但這關聯沒有被廣泛研究。識別這些風險因素對需要進一步評估有腹內受傷可能的病人的優先次序會有幫助。**方法：**於 2004 年因嚴重鈍性創傷而到一所一級創傷中心求診的全部 622 名成年病人（傷勢嚴重性得分>12），進行了一個回顧性記錄審查。使用 SAS 統計電腦軟件以單變及多元分析各項腹內受傷的臨床預報因子。**結果：**於多元分析，找出 4 個重要的腹內受傷預報因子：「集中評估創傷超聲波檢查」呈陽性（機會率＝ 48.5, p<0.0001）、盤骨折（機會率＝ 2.4, p=0.0002）、插入胸管（機會率＝ 1.8, p=0.0211）及收縮血壓，每 10 mmHg 下降顯示風險增加 14%（機會率＝ 0.986, p=0.001）。如所有

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4 個預報因子不存在，預料腹內沒有受傷的特異性是 0.776（95% 置信區間 0.741 至 0.808）及似然比 2.7（95% 置信區間 2.0 至 3.5）。**結論：**這研究暗示陽性的「集中評估創傷超聲波檢查」、盤骨折、插入胸管及收縮血壓在成年鈍性創傷病人（創傷嚴重性得分>12）是重要的腹內受傷預報因子。所有 4 個預報因子如皆不存在時，會有較低的腹內受傷風險。

Keywords: Abdominal injuries, bone fractures, diagnostic imaging, multiple trauma, ultrasonography

關鍵詞：腹部受傷、骨折、造影診斷、多重創傷、超聲波檢查法

Introduction

Intra-abdominal injury (IAI) in blunt trauma patients is associated with significant morbidity and mortality; therefore the early and accurate recognition of this condition is essential. Physical examination is often unreliable, sometimes because patients may have concomitant head injury and/or distracting pain, or are under the influence of alcohol or drugs.[1,2] Diagnostic peritoneal lavage (DPL) was for many years the tried and tested modality, but in recent years it has been largely replaced by non-invasive options like computed tomography (CT) scans and focused assessment with sonography for trauma (FAST).

Unlike DPL or FAST, whose primary role is the detection of haemoperitoneum, CT has the added advantage of being able to provide more information with regard to the type and extent of intra-abdominal injury, including retroperitoneal injuries. It can also be extended 'beyond' the abdomen to visualise the spine, chest and pelvis. It is however not without drawbacks, being expensive, time-consuming, potentially hazardous for unstable patients, and associated with exposure to radiation.[3] Over-reliance on CT may result in hasty and inadequate resuscitation in the trauma room, or delays in more important interventions such as pelvic immobilisation. Some rural hospitals may either not have the luxury of a dedicated round-the-clock CT scanner for trauma patients, or not have 24-hour support to interpret such scans.

Since the early 90s when it was first introduced to North America, the use of ultrasonography for trauma has been increasingly widespread, and its roles and functions have been increasingly well defined.[4,5] Some studies claim that the use of FAST resulted in fewer abdominal CT scans being obtained, yet other authors have raised concerns about the false negative rates of FAST and consequent underdiagnosis of IAI.[6-8]

Certain clinical features or injuries may be predictive of IAI, but this association has not been widely studied. In facilities without widespread availability of definitive imaging services or surgical backup, identification of such risk factors may be useful to prioritise patients in need for further evaluation of possible IAI.

In this study, the authors try to determine clinical predictors that could help identify the patient at high risk for IAI. In addition, we attempt to determine a combination of clinical features that, when absent, may suggest a lower risk of IAI in blunt trauma patients, therefore lowering the urgency and priority to definitively image the abdomen.

Materials and methods

This was a retrospective chart review conducted at Sunnybrook Health Sciences Centre, one of two level 1 trauma centres in Toronto, Ontario. Records of all adult blunt trauma patients referred to the trauma team in our centre in the year 2004 were obtained via the hospital trauma registry. Blunt trauma patients may be referred to the trauma team in our centre for suspected multi-system trauma and based on mechanism of injury. Single system blunt trauma injuries are typically not referred to the trauma team in our centre. Patients were excluded if they sustained penetrating trauma, had predominant burns injury, were less than 18 years of age, or had an Injury Severity Score (ISS) of 12 or below, since such cases are excluded from the Ontario Trauma Registry.

Information obtained from chart review included patient demographics, mechanism of injury (motor vehicle collision [MVC] driver vs. non-driver), initial trauma room vital signs, Glasgow Coma Scale (GCS 15 vs. GCS <15), laboratory values such as blood alcohol (present vs. absent) and arterial base excess (BE), specific interventions (intubation, chest tube insertion, packed cell transfusion, exploratory laparotomy), FAST and abdominal CT findings (if performed), and presence of specific injuries: head injury (Abbreviated Injury Scale [AIS] >1), pelvic fracture (AIS >1), femoral fracture (AIS >3), and intra-abdominal injury (abdominal AIS >1).

CT scans were performed on a General Electric™ (Fairfield, Connecticut) Lightspeed QXI 4-slice helical scanner with a maximum speed of 0.5 second/rotation. A positive abdominal CT was defined, based on the official radiology report, as the presence of any injury to a solid organ, bowel, mesentery, diaphragm or bladder; or the presence of free fluid consistent with haemorrhage, pneumoperitoneum or retroperitoneal haematoma.

FAST was performed by the attending trauma team leader using a Siemens™ (New York, NY) Sonoline Adara™ with a 3.5 MHz convex array transducer. A positive FAST examination was defined as the presence of free peritoneal fluid in the right upper quadrant hepato-renal fossa, the left upper quadrant spleno-renal recess, or the suprapubic pouch of Douglas. No attempt was made to quantify the amount of free peritoneal fluid.

IAI was defined as any injury to an abdominal solid organ, bowel, mesentery, diaphragm or bladder identified either by CT or during laparotomy, or in the event of patient death before CT or laparotomy, by the Trauma Registry's documentation of abdominal AIS >1.

Of the 20 measured variables, 10 variables which were thought to be the most predictive of IAI based on the authors' a priori knowledge were selected and simultaneously entered for subsequent multiple logistic regression analysis: age, gender, mechanism of injury, positive blood alcohol, initial trauma room systolic blood pressure (SBP), GCS, FAST, intubation, chest tube insertion, and pelvic fracture. Statistical analysis was performed using SAS® (Statistical Analysis System) statistical software. The Research Ethics Board of Sunnybrook Health Sciences Center approved the study.

Results

Of 777 trauma patients seen in the year 2004 with ISS greater than 12, 155 patients had penetrating trauma, predominant burns or were less than 18 years of age and were excluded. The remaining 622 patients fulfilled the study criteria and were enrolled. The patients ranged from 18 to 95 years of age (mean age 43), and 431 patients (69.3%) were male. Patient demographics and characteristics are shown in Table 1.

As expected, there were significant differences between patients with and without IAI in terms of ISS, SBP, base excess (BE), FAST, chest tube, pelvic fracture, mechanism of injury and intensive care unit (ICU) length of stay (LOS). No statistically significant difference was found in terms of patient age, gender, alertness (GCS=15 or otherwise), overall mortality, intubation, or blood alcohol.

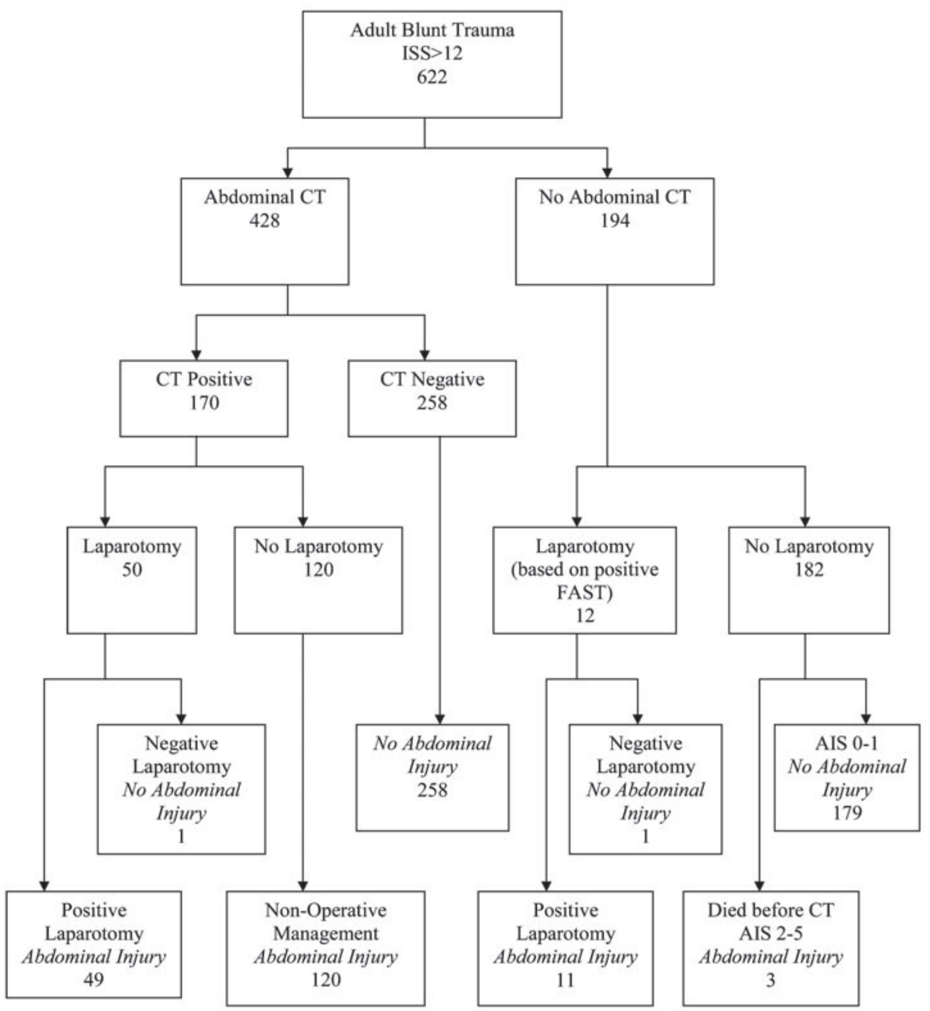
A total of 183 patients had intra-abdominal injury, of which 49 had a positive abdominal CT followed by exploratory laparotomy, 11 had exploratory laparotomy without a prior abdominal CT, 120 had a positive abdominal CT followed by non-operative management, and 3 died in the trauma room before definitive abdominal CT or laparotomy. The remaining 439 patients had no intra-abdominal injury, of which 258 had a negative abdominal CT, 2 had negative exploratory laparotomy, while 179 had no clinical indication for abdominal CT. A diagram showing the various categories of patients can be found in Figure 1.

Following multivariate analysis, 4 significant predictors of intra-abdominal injury were found (Table 2). When the multivariate analysis was restricted to only these 4 significant variables, the

Table 1. Demographics and characteristics of the study population

Characteristic	All patients	Abdominal injury	No abdominal injury	p-value
Age, year, mean	43.4	40.0	44.8	0.0058
Sex, % male	69.3	66.1	70.6	0.3115
ISS, mean	29	36	26	<0.0001
GCS=15, % of patients	53.4	55.2	52.6	0.6187
Mortality, % of patients	12.9	16.4	11.4	0.1170
SBP, mmHg	136	127	140	<0.0001
BE, mmol/L	0.2	-1.6	1.1	<0.0001
FAST, % positive	12.7	40.4	1.1	<0.0001
Chest tube insertion, % of patients	19.1	31.7	13.9	<0.0001
Intubation, % of patients	37.6	39.9	36.7	0.5068
Pelvic fracture, % of patients	26.8	42.6	20.3	<0.0001
Mechanism, % MVC driver	48.4	59.6	43.7	0.0004
Blood alcohol, % positive	17.8	13.1	19.8	0.0608
ICU LOS, days	4.0	5.5	3.4	0.0281

BE=base excess; FAST=focused assessment with sonography for trauma; GCS=Glasgow Coma Scale; ICU=intensive care unit; ISS=Injury Severity Score; LOS=length of stay; MVC=motor vehicle collision; SBP=systolic blood pressure



AIS=Abbreviated Injury Scale; CT=computed tomography; FAST=focused assessment with sonography for trauma; ISS=Injury Severity Score

Figure 1. Details of the 622 enrolled adult blunt trauma patients.

4-variable model fitted the data statistically as well as the original full 10-variable model. The independent odds ratios associated with each factor were: positive FAST (OR=52.9, p<0.0001), presence of pelvic fracture (OR=2.5, p<0.0001), presence of chest tube (OR=2.1, p=0.0048), and systolic blood pressure (OR=0.987, p=0.0017).

An analysis of the ability of the 3 binary variables alone in predicting IAI revealed that FAST was by far the strongest predictor (Table 3). Taken on its own, a positive FAST is highly specific in the diagnosis of IAI (specificity 0.989, 95% CI 0.974 to 0.995), but a negative FAST had poor sensitivity in ruling out IAI (sensitivity 0.404, 95% CI 0.336 to 0.477). Both chest tube insertion and pelvic fracture alone had fair specificity but poor sensitivity in the diagnosis of IAI; with chest tube: specificity 0.861 (95% CI 0.826 to 0.89), sensitivity 0.317 (95% CI 0.254 to 0.388) and pelvic fracture: specificity 0.797 (95% CI 0.757 to 0.832), sensitivity 0.426 (95% CI 0.357 to 0.499).

A combination of negative FAST, negative pelvic fracture, negative chest tube insertion, and SBP greater than 120 mmHg predicts the absence of IAI with a LR of 2.7 (95% CI 2.0 to 3.5). In our patient population, given a pre-test probability of no abdominal injury of 0.7, this combination of clinical findings will result in a post-test probability of 0.865.

Table 2. Multivariate logistic regression

Variable	OR (95% CI)	p-value
FAST	48.5 (18.6, 126.3)	<0.0001
Chest tube	1.8 (1.1, 3.1)	0.0211
Pelvic fracture	2.4 (1.5, 3.8)	0.0002
Systolic blood pressure	0.986 (0.978, 0.994)	0.001
MVC driver	1.5 (0.9, 2.3)	0.0968
Blood alcohol	0.7 (0.4, 1.4)	0.3152
Age	0.997 (0.986, 1.009)	0.6663
Glasgow coma scale = 15	1.3 (0.7, 2.4)	0.4704
Intubation	1.4 (0.8, 2.7)	0.2712
Male sex	1.3 (0.8, 2.1)	0.3577

FAST=focused assessment with sonography for trauma; MVC=motor vehicle collision

Table 3. Performance of variables in predicting intra-abdominal injury

Variable	LR+ (95% CI)	LR- (95% CI)	PPV (95% CI)	NPV (95% CI)	Specificity (95% CI)	Sensitivity (95% CI)
FAST positive	35.50 (14.59, 86.38)	0.60 (0.53, 0.68)	0.937 (0.86, 0.97)	0.799 (0.76, 0.83)	0.989 (0.974, 0.995)	0.404 (0.336, 0.477)
Chest tube positive	2.28 (1.66, 3.13)	0.79 (0.71, 0.88)	0.487 (0.399, 0.576)	0.751 (0.712, 0.787)	0.861 (0.826, 0.89)	0.317 (0.254, 0.388)
Pelvic fracture positive	2.10 (1.64, 2.7)	0.72 (0.63, 0.82)	0.467 (0.393, 0.543)	0.769 (0.728, 0.806)	0.797 (0.757, 0.832)	0.426 (0.357, 0.499)
Combination*	2.67 (2.02, 3.54)	0.52 (0.45, 0.59)	0.865 (0.835, 0.89)	0.447 (0.407, 0.487)	0.776 (0.741, 0.808)	0.599 (0.559, 0.638)

FAST=focused assessment with sonography for trauma

* Combination of FAST negative, chest tube negative, pelvic fracture negative and systolic blood pressure >120 mmHg in predicting absence of intra-abdominal injury.

Discussion

The accurate diagnosis of IAI in a timely and cost effective manner in blunt trauma patients remains challenging. Reliance on the physical examination may not be the ideal approach as it can often be altered by the presence of head injury, distracting injury or pain elsewhere, or drugs and/or alcohol. As such, in many trauma centres, it has almost become 'routine' to obtain an abdominal CT to definitively exclude IAI in stable blunt trauma patients, the presence of a negative FAST notwithstanding. However, as previously discussed, this approach is not without its drawbacks. How then, can definitive imaging be used more selectively? What clinical features can predict the presence or absence of IAI? Several studies have been attempted to answer this.

In a prospective study, Poletti et al found that the best combination of criteria to identify a major abdominal injury was obtained when sonography, chest radiography, and three laboratory parameters were normal, but only 22% of patients without major injuries fulfilled these criteria.[9] The only combination of criteria that completely excluded intra-abdominal injury was obtained when clinical criteria combined with a GCS >13, bedside radiological studies, and laboratory data were all normal, but only 12% of patients fulfilled these criteria. He concluded that the majority of patients with suspicion of blunt abdominal trauma should therefore undergo extended clinical observation or abdominal CT.

Mackersie et al found, in a retrospective study, that arterial base deficit less than -3 mEg/L, major chest injury, hypotension, and pelvic fractures were found to significantly increase the chance of IAI.[10] A subsequent study by Garber et al, applying this clinical prediction rule to a retrospective cohort of patients, found that it was highly accurate in identifying patients with positive CT findings, and suggested that prospective use of such a rule could reduce the number of CT scans ordered without missing significant injuries.[11] In contrast, a prospective study by Beck et al found that an abnormal pelvic X-ray and intubation were significant risk factors for a positive CT scan.[12]

In this present retrospective chart review of 622 adult blunt trauma patients with ISS of greater than 12 over a one-year period, there was a 29.4% incidence of IAI. In terms of univariate analysis, there was significant difference between those with IAI and those without in terms of FAST, ISS, SBP, BE, chest tube, pelvic fracture, mechanism and ICU LOS. Interestingly, there was no statistically significant difference in terms of patient age, gender, alertness (GCS=15 or otherwise), overall mortality, intubation, or blood alcohol. After simultaneously entering the 10 selected variables into a multivariate logistic regression analysis, 4 variables achieved statistical significance in predicting IAI: positive FAST, presence of pelvic fracture, presence of chest tube, and systolic blood pressure.

These findings are remarkably consistent with the results of the previous study by Mackersie et al,[10] with the exception of BE. In our chart review, BE was performed in only 513 of the 622 enrolled patients. It could not be determined whether there was a systematic bias in testing (or not testing) BE, therefore although it was found to be statistically significant on univariate analysis, it was not subsequently entered into the multivariate logistic regression analysis.

Although combining FAST with the other significant variables did not result in a stronger predictive model, a combination of these variables may be helpful in determining which patients are unlikely to have a serious abdominal injury and in whom it is likely safe to delay abdominal CT imaging. A combination of negative FAST, no pelvic fracture, no chest tube insertion, and SBP greater than 120 mmHg predicts the absence of intra-abdominal injury with a specificity of 0.776 (95% CI 0.741 to 0.808) and a LR of 2.7 (95% CI 2.0-3.5). Given a pre-test probability (of no abdominal injury) of 0.7, this combination of clinical findings will result in a post-test probability of 0.865.

A total of 35 patients had intra-abdominal injury yet had a negative FAST, no pelvic fracture, no chest tube insertion and SBP >120 mmHg. Most (32/35) of these abdominal injuries identified on CT were non-life threatening and were managed non-operatively, and the deferral of definitive abdominal imaging would unlikely have resulted in adverse consequences for the majority of these patients. There were 3 laparotomies amongst these 35 patients. Patient #1 was a 77-year-old male involved in a motor vehicle collision with a mesenteric and sigmoid colon serosal haematoma. Patient #2 was a 76-year-old male pedestrian struck who had severe closed head injury and some bleeding from an underlying hepatocellular carcinoma of the liver. Patient #3 was a 26-year-old male motorcyclist with severe closed head injuries. CT identified a retroperitoneal haematoma and a suspected bowel injury, for which a negative laparotomy was done. Amongst these 35 patients with 'missed' abdominal injury according to our criteria, there were 5 deaths: patients #2 and #3 as above, plus 3 others with severe closed head injury and 'incidental' intra-abdominal injuries picked up on CT: the first had a small liver laceration, the second had bilateral perinephric fluid collections with no lacerations seen, and the third had a mild injury to the left kidney. The abdominal injuries do not appear likely to have been major contributors to these patients' deaths.

As most of the intra-abdominal injuries 'overlooked' by this combination of findings were minor, the absence of all four factors may be useful in predicting the absence of life-threatening IAI. This may be of special relevance in rural hospitals and other facilities with limited access to round-the-clock CT imaging of the abdomen, surgical backup, or transfer.

This study has several limitations. We excluded patients who had ISS of 12 and below since such patients are not included in the Ontario Trauma Registry. As such, our results are generalisable to more serious trauma patients. As a retrospective chart review, it is only as good as the quality of the available data. Specifically, the 109 patients who had missing BE values meant that BE could not be entered into multivariate analysis as originally intended. There was also no data on the presence or absence of physical findings such as abdominal tenderness, although many previous studies have suggested that clinical examination is a poor predictor of abdominal injury. The selection of the variables to be entered into multivariate analysis was done to the best of the authors' a priori knowledge regarding IAI, but it is possible that more important variables were unknowingly omitted. Finally, these results should be prospectively validated.

Conclusion

From this retrospective series, 4 variables were found to be statistically significant in predicting IAI: a positive FAST, the need for chest tube insertion, presence of pelvic fracture, and SBP. A combination of negative FAST, no pelvic fracture, no chest tube insertion and a SBP of >120 mmHg is associated with a reduced risk of IAI. In trauma patients with none of the 4 variables, it may be safe to undertake definitive abdominal imaging on a less urgent basis.

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