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Identifying patients at risk for high-grade intra-abdominal hypertension following trauma laparotomy

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ABSTRACT

Background: Abdominal Compartment Syndrome (ACS) is an uncommon but deleterious complication after trauma laparotomy. Early recognition of patients at risk of developing ACS is crucial for their outcome. The aim of this study was to compare the characteristics of patients who developed high-grade intra-abdominal hypertension (IAH) (*i.e.*, grade III or IV; intra-abdominal pressure, IAP >20 mmHg) following an injury-related laparotomy versus those who did not (*i.e.*, IAP ≤20 mmHg).
Methods: A retrospective analysis of consecutive trauma patients admitted to a level 1 trauma centre in Australia between January 1, 1995 and January 31, 2010 was performed. A comparison was made between characteristics of patients who developed high-grade IAH following trauma laparotomy versus those who did not.
Results: A total of 567 patients (median age 31 years) were included in this study. Of these patients 10.2% (58/567) developed high-grade IAH of which 51.7% (30/58) developed ACS. Patients with high-grade IAH were older ($p < 0.001$), had a higher Injury Severity Score ($p < 0.001$), larger base deficit ($p < 0.001$) and lower temperature at admission ($p = 0.011$). In the first 24 h of admission, patients with high-grade IAH received larger volumes of crystalloids ($p < 0.001$), larger volumes of colloids ($p < 0.001$) and more units of packed red blood cells ($p < 0.001$). Following surgery prolonged prothrombin ($p < 0.001$) and partial thromboplastin times ($p < 0.001$) were seen. The patients with high-grade IAH suffered higher mortality rates (25.9% (15/58) vs. 12.2% (62/509); $p = 0.012$).
Conclusion: Of all patients who underwent a trauma laparotomy, 10.2% developed high-grade IAH, which increases the risk of mortality. Patients with acidosis, coagulopathy, and hypothermia were especially at risk. In these patients, the abdomen should be left open until adequate resuscitation has been achieved, allowing for definitive surgery.
Level of evidence: This is a level III retrospective study.

Background

Trauma is the leading cause of death in people aged 1 to 44 years and exsanguination is a common cause of death [1]. Such active bleeding focus is frequently located intra-abdominally [2]. In patients presenting to hospital following severe injury, haemodynamic instability or acute abdominal findings can mandate laparotomy. Laparotomy in this setting may be lifesaving.

Despite improved survival following laparotomy, patients are still at risk of developing abdominal compartment syndrome (ACS) [3,4]. ACS is a syndrome of intra-abdominal hypertension (IAH) with new onset or worsening organ failure. The World Society of the Abdominal Compartment Syndrome (WSACS) defines ACS as an intra-abdominal pressure (IAP) >20 mmHg with clinical signs of new organ failure, such as renal failure or increasing ventilation difficulties [5,6]. ACS is termed primary when it originates from intra-abdominal pathology, secondary when originating from an extra-abdominal source and tertiary or recurrent when ACS occurs in an already decompressed abdomen [7]. WSACS defines IAH as an IAP ≥12 mmHg and introduced a IAH grading system for increasing severity with grades from I to IV [8]. Grade I (IAP 12–15 mmHg) and II (IAP 16–20 mmHg) are referred to as low-grade IAH and

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Grade III (IAP 21–25 mmHg) and IV (IAP>25 mmHg) are referred to as high-grade IAH. IAH and ACS result from decreased abdominal wall compliance and/or increased intra-abdominal volumes (fluid, oedema).

ACS in isolation is generally treated through medical means or by decompressing the abdomen. The resulting laparostomy can be kept open for several days to a week using a temporary abdominal closure technique (TAC) [9]. Surgeons can consider using TAC following trauma laparotomy if a patient is likely to develop IAH or ACS. However, a prolonged open abdomen is associated with higher morbidity including intra-abdominal infections, sepsis, anastomotic leakage, intestinal fistulae and sepsis [10–13]. Knowledge of specific risk factors for IAH or ACS following trauma laparotomy may help the surgeon to mitigate these risks and improve outcomes. The aim of this study was to compare characteristics of patients who developed high-grade IAH following trauma laparotomy versus those patients who did not.

Methods

A retrospective analysis was performed in trauma patients who underwent trauma laparotomy in a level I trauma centre in Australia. This trauma centre serves over 1 million inhabitants and admits more than 350 trauma patients annually with an injury severity score (ISS) greater than 15 [14]. Data of admitted trauma patients were prospectively collected by trained trauma nurse coordinators [15]. This registry has been recording more than 154 different variables for seriously injured patients, and has done so since 1994.

Consecutive trauma patients who underwent trauma laparotomy within 24 h of admission between January 1, 1995 and January 31, 2010 were included. Trauma registry data were collected as was information from clinical notes. This study was approved by the hospital's Human Research Ethics Committee.

Data collection included patient demographics, IAP's, information on organ function and diagnosis of ACS, abdominal decompression, ISS, shock, mechanism of injury, temperature on admission, lactate, base deficit, pH, haemoglobin level, resuscitation fluid(s), resuscitation volume, survival, and ICU/hospital lengths of stay. IAH and ACS were defined in accordance with the WSACS guidelines [6]. Data were complete, unless specified differently in the Table footnotes.

Data were analysed using SPSS version 16 (SPSS Inc. Released 2007. SPSS for Windows, Version 16.0. Chicago, SPSS Inc.). Youden index was analysed using MedCalc version 14.10.2 (MedCalc Software, Ostend, Belgium). Inspecting frequency histograms and *Q–Q* plots revealed that the majority of continuous variables deviated from a standard normal distribution. Therefore, all continuous variables were regarded as non-normal and are shown as median values with first and third quartiles. Differences between patients with versus without high-grade IAH were tested using a Mann–Whitney *U*-test (continuous variables), a Fisher's exact test or Chi-squared test (categorical variables). Binary logistic regression analysis was performed in order to determine the strength of the association between covariates (independent variables) and the IAH grade (dependent variable; high-grade versus no high-grade IAH). Odds ratios are presented with 95% confidence intervals. The Hosmer–Lemeshow test statistic (Chi-squared value) with corresponding *p*-value is given as measure of model calibration, and the area under the Receiver Operating Characteristic (ROC) curve is provided as measure of discriminatory power. The Youden Index ($J = \max(\text{sensitivity} + \text{specificity} - 1)$), representing the maximum vertical distance between the ROC curve and the diagonal line, was calculated in order to determine at which value of the evaluated variable the sum of sensitivity and specificity had the highest value. The Youden index is shown with its 95% confidence interval following bootstrapping (1000 replicates and 900 random-number seeds). For continuous variables the optimal threshold value is also shown. *p*-Values <0.05 were considered statistically significant.

Results

Over a 16-year period 583 trauma patients presented to the emergency department and underwent trauma laparotomy. Of these patients, 16 underwent trauma laparotomy more than 24 h following admission or were pregnant and therefore were not included in the study.

Baseline characteristics of the 567 included patients are shown in Table 1. Patients had a median age of 31 years, the majority of these patients were male, two-thirds sustained blunt injury and less than half had circulatory shock (defined by SBP < 90 mmHg) at the time of presentation to the emergency department. Of the included patients 10.2% (58/567) developed an IAP >20 mmHg, of which 51.7% (30/58) developed ACS. In order to compare characteristics and potential risk factors for ACS following trauma laparotomy, patients were divided into two separate groups; patients with an IAP ≤20 mmHg (no high-grade IAH, *N* = 509) and patients with an IAP >20 mmHg (high-grade IAH, *N* = 58). The patients with high-grade IAH following trauma laparotomy were older ($p < 0.001$), had a higher injury severity score (ISS;

Table 1
Patient demographics for the overall population as well as separated for the groups with an IAP ≤20 mmHg and >20 mmHg.

Variable	Overall (*N* = 567)	IAP ≤20 (*N* = 509)	IAP > 20 (*N* = 58)	*p*-Value	OR (95% CI)	H–L test (Chi-square)	AUC	Youden Index (95% CI; threshold)
Age (year)	31 (23–44)	30 (22–42)	50 (34–65)	<0.001	**1.05 (1.04–1.07)**	7.83 (0.450)	0.75	0.39 (0.26–0.47; >35)
Males	452 (79.7%)	404 (79.4%)	48 (82.8%)	0.680[B]	1.25 (0.61–2.55)[D]	N.A.	(0.52)[G]	0.03 (0.00–0.10; N.A.)
ISS	21 (13–34)	20 (11–34)	34 (22–44)	<0.001	**1.03 (1.01–1.04)**	**24.82 (0.002)**	0.70	0.35 (0.25–0.46; >25)
Circulatory shock[A]	220 (38.8%)	179 (35.2%)	41 (70.7%)	<0.001[C]	**4.51 (2.46–8.27)**[E]	N.A.	(0.68)	0.36 (0.23–0.47; N.A.)
Blunt Injury	374 (66.0%)	327 (64.2%)	47 (81.0%)	0.012[B]	**2.38 (1.20–4.70)**[F]	N.A.	(0.58)	0.17 (0.04–0.26; N.A.)
Penetrating Injury	193 (34.0%)	182 (35.8%)	11 (19.0%)					

ACS, abdominal compartment syndrome; AUC, area under the receiver operating characteristic (ROC) curve. H–L, Hosmer–Lemeshow goodness of fit test; IAP, intra-abdominal pressure (mmHg); ISS, injury severity score; N.A., not applicable; OR, odds ratio. Descriptive data are shown as median with the P_{25}–P_{75} between brackets or as number with the percentage between brackets.

[A] Data were missing for 16 patients (15 in the ≤20 mmHg group and 1 in the >20 mmHg group).

p-Values are calculated using Mann–Whitney *U*-test, [B] Fisher's exact test, or [C] Chi-squared test.

Odds ratios are determined using a binary logistic regression and are expressed for the comparison of [D] males versus females as reference category; [E] Unstable versus stable; [F] Blunt versus penetrating trauma. Odds ratios are given with the 95% confidence interval (CI) between brackets. The H–L statistic is given with the *p*-value between brackets. Statistically significant OR's and H–L values are shown in boldface. [G] The AUC values for these binary variables are based on only a single value of sensitivity and specificity. The Youden Index is shown with the 95% CI and (for continuous variables) the threshold value between brackets. For categorical variables, the threshold value is not applicable (N.A).