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ORIGINAL ARTICLE

Causes and associations with mortality in patients with pelvic ring injuries with haemorrhagic shock

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Abstract

Background High energy pelvic ring injuries are associated with significant morbidity and mortality and can be accompanied by haemorrhagic shock following associated vascular injury. This study evaluated the causes and predictors of mortality in haemodynamically unstable pelvic fractures.

Methods This retrospective observational study at a Major Trauma Centre reviewed 938 consecutive adult patients (≥ 18yrs) with pelvic ring injuries between December 2014 and November 2018. Patients with features of haemorrhagic shock were included, defined as: arrival Systolic BP < 90 mmHg, Base Deficit ≥ 6.0 mmol/l, or transfusion of ≥ 4 units of packed red blood cells within 24 h.

Results Of the 102 patients included, all sustained injuries from high energy trauma, and 47.1% underwent a haemorrhage control intervention (Resuscitative Endovascular Balloon Occlusion of the Aorta—REBOA, Interventional Radiology—IR, or Laparotomy). These were more often required following vertical shear injuries (OR 10.7, $p = 0.036$).
Overall, 33 patients (32.4%) died; 16 due to a head injury, and only 2 directly from acute pelvic exsanguination (6.1%). Multivariable logistic regression demonstrated that increasing age, Injury Severity Score, Abbreviated Injury Scale (AIS) Head ≥ 3 and open pelvic fracture were all independent predictors of mortality, and IR was associated with reduced mortality. Lateral Compression III (LC3) injuries were associated with mortality due to multiple organ dysfunction syndrome (MODS).

Conclusion Haemodynamically unstable patients with pelvic ring injuries have a high mortality rate, but death is usually attributed to other injuries or later complications, and not from acute exsanguination. This reflects improvements in resuscitative care, transfusion protocols, and haemorrhage control techniques.

Keywords Pelvis · Pelvic fracture · Trauma · Haemodynamic instability · Haemorrhage

Introduction

The pelvic ring is a highly mechanically stable structure, the disruption of which requires significant force in non-fragility patients. When this occurs, the injury is associated with marked soft tissue, neurovascular or visceral trauma [1, 2]. Intrapelvic vascular structures (venous plexi, veins and arteries) are poorly accessible and, when disrupted, can quickly result in significant haemorrhage and haemodynamic instability, requiring urgent life-saving interventions [3]. As

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such, pelvic fractures with haemodynamic instability have previously been associated with a significant mortality risk, ranging from 30 to 46.5% [1, 4–9]. In addition, patients with pelvic fractures are frequently burdened by multiple other injuries related to high energy mechanisms resulting in significant morbidity [10, 11].

Established (angio-embolisation, pre-peritoneal packing) and novel (resuscitative endovascular balloon occlusion of the aorta—REBOA) haemorrhage control interventions have the potential to reduce mortality in haemodynamically unstable patients with these injuries [9, 12–14]. Whilst the utility of these interventions is increasingly understood [4, 13, 15, 16], the association between injury pattern, surgical fixation and outcome (length of stay and mortality) is less clear. This study evaluated a contemporary group of patients with pelvic fractures with associated haemorrhagic shock, and the primary outcome was mortality risk and predictors of mortality, and causes and associations with death. The secondary outcomes were the patterns of pelvic ring injury, haemorrhage control interventions, pelvic surgical fixation, and length of stay.

Methods

This was a retrospective observational study, conducted at a high volume inner-city Major Trauma Centre in the United Kingdom. Between December 2014 and November 2018, consecutive patients with pelvic injuries were identified from the locally maintained, prospectively collected database of trauma patients using Abbreviated Injury Scale (AIS) codes. The study was registered and approved by the local clinical effectiveness department. The NHS Research Ethics Committee decision tool excluded need for ethical review.

All adult patients (≥ 18 years old) with a pelvic ring injury and features of haemorrhagic shock were included. Haemorrhagic shock was defined as Systolic Blood Pressure (SBP) on arrival < 90 mmHg, Base Deficit (BD) on arrival ≥ 6.0 mmol/l, or transfusion of 4 or more units of packed red blood cells (PRBC) in the first 24 h. These features were chosen as they are well-established indicators of haemodynamic compromise [2, 17–19]. The presence of any one of these features led to inclusion, although many patients had two or three. Radiographs and computed tomography (CT) images were reviewed using the local Picture Archiving and Communication System (PACS) to identify those with a pelvic ring injury. Those with isolated acetabular or iliac wing fractures, without evidence of pelvic ring injury, were excluded. PACS and electronic notes were reviewed to gather additional data regarding the causes of mortality, as well as classify the pelvic injury pattern according to the Young and Burgess classification system [20, 21], review haemorrhage control details, and characterise pelvic fixation method and timing. All relevant case notes and images were independently reviewed by two authors, with at least one being a fellowship-trained consultant pelvic and acetabular surgeon. In the cases of discrepancies in injury classification, a third, fellowship-trained reviewer (senior author) reviewed the case to reach consensus.

The primary outcome measure evaluated was cause of mortality, as well as predictive factors on multivariable regression. Secondary outcomes were haemorrhage control intervention on arrival, associations with pelvic injury types, pelvic fixation method and timing, hospital length of stay (HLOS), intensive care unit length of stay (ICULOS), Injury Severity Score (ISS), and Abbreviated Injury Scale (AIS) for other body regions (≥ 3 considered to be a severe injury). All patients were followed up until death or discharge, and patients surviving until discharge were assumed to have survived for the purposes of analysis.

Statistical methods

Statistical analysis was performed using JASP Version 0.16.2 [22]. Continuous data were tested for normality using distribution plots and the Shapiro–Wilk test. Normally distributed data were reported as mean and standard deviation (SD), and nonparametric data were reported as median and interquartile range (IQR). Categorical data were presented as frequency (n) and percentage (%). For dichotomous categorical variables, Fisher's Exact test was used, due to small sample size. Student's *t* test was used for comparing normally distributed continuous data, and Mann–Whitney *U* test was used for comparing nonparametric continuous data between two groups. Logistic regression was used to analyse the association between multiple variables and mortality risk, as well as associations between pelvic injury types and haemorrhage control interventions. Variables which were found to be statistically significantly associated with mortality on univariate analysis ($p < 0.1$), were analysed with multivariable logistic regression with a significance level of $p < 0.05$.

Results

During the 4-year study period, 938 patients with pelvic injuries were identified. No major institutional changes in resuscitation practice were implemented during this time, with transfusion and resuscitation protocols having been stable since 2010 [2]. After exclusions, 102 adult patients with pelvic ring injuries and features of haemorrhagic shock were included.

Sixty-six patients were male (64.7%), and the median age was 43 (range 19–90) years (Table 1). The most

Table 1 Baseline characteristics, methods of haemorrhage control and pelvic fixation for 102 haemodynamically unstable patients with pelvic fractures

	Missing data *n* (%)	*n* (%)/Mean ± SD/Median (IQR)
Demographics		
Age	2 (2.0%)	43 (range 19–90)
Gender (male)	0 (0%)	66 (64.7%)
Mechanism of Injury	0 (0%)	
Fall > 2 m		32 (31.4%)
Pedestrian vs. Vehicle		25 (24.5%)
Pedestrian vs. Train		10 (9.8%)
RTC–Car		13 (12.7%)
RTC–Cyclist		9 (8.8%)
RTC–Motorcyclist		9 (8.8%)
Crushed		4 (3.9%)
Injury Scores	0 (0%)	
ISS		41.4 ± 16.5
AIS Head ≥ 3		39 (38.2%)
AIS Chest ≥ 3		61 (59.8%)
AIS Abdomen ≥ 3		30 (29.4%)
AIS Spine ≥ 3		15 (14.7%)
AIS Lower extremity & Pelvis ≥ 3		93 (91.2%)
Haemodynamic Parameters		
SBP on arrival (mmHg)	12 (11.8%)	84.9 ± 27.4 (51 patients < 90)[#]
HR on arrival (bpm)	11 (10.8%)	106.0 ± 34.7
BD on arrival (mmol/l)	43 (42.2%)	8.48 ± 7.46 (39 patients ≥ 6)[#]
Lactate on arrival (mmol/l)	39 (38.2%)	4.3 (2.95–7.5), mean = 5.52
PRBC transfusion within 24 h (units)	0 (0%)	6.0 (2–11) (74 patients ≥ 4)[#]
Platelet transfusion within 24 h (pools)	0 (0%)	2.0 (1–3)
FFP transfusion within 24 h (units)	0 (0%)	7.5 (4–12)
Cryoprecipitate transfusion within 24 h (units)	0 (0%)	2.0 (1.25–4)
Length of Stay		
HLOS (days)*	0 (0%)	41.0 (24.7–73.2)
ICULOS (days)*	0 (0%)	8.5 (0–17.5)
ICU admission	0 (0%)	72 (70.6%)
Mortality	0 (0%)	33 (32.4%)
Haemorrhage Control Intervention	0 (0%)	
None (binder only)		54 (52.9%)
Laparotomy		17 (16.7%)
Laparotomy + other surgery		2 (2.0%)
Other surgery		3 (2.9%)
IR		13 (12.7%)
IR + laparotomy		2 (2.0%)
REBOA		3 (2.9%)
REBOA + laparotomy		5 (4.9%)
REBOA + IR		1 (1.0%)
REBOA, laparotomy + IR		2 (2.0%)
Pelvic Fixation	0 (0%)	
Non-operative management		18 (17.6%)
None (died)		27 (26.5%)
IS Screw(s) alone		8 (7.8%)
IS Screw(s) + external fixator		1 (1.0%)

Table 1 (continued)

	Missing data n (%)	n (%)/Mean ± SD/Median (IQR)
IS screw(s) + INFIX		25 (24.5%)
IS Screw(s) + INFIX + other pelvic fixation		5 (4.9%)
IS Screw(s) + other pelvic fixation		9 (8.8%)
IS Screw(s) + pubic symphysis plate		6 (5.9%)
IS Screw(s) + pubic symphysis plate + other pelvic fixation		3 (2.9%)

RTC: Road traffic collision, *ISS*: Injury severity score, *AIS*: Abbreviated injury scale, *SBP*: Systolic blood pressure, *HR*: Heart rate, *BD*: Base deficit, *PRBC*: Packed red blood cells, *FFP*: Fresh frozen plasma, *HLOS*: Hospital length of stay, *ICULOS*: Intensive care unit length of stay, *ICU*: Intensive care unit, *IR*: Interventional radiology, *REBOA*: Resuscitative endovascular balloon occlusion of the aorta, *IS*: Iliosacral

*HLOS and ICULOS for surviving patients. # Inclusion criteria for study population. Normally distributed values expressed as mean ± SD, non-parametric values expressed as median (IQR) unless stated otherwise

common injury patterns were lateral compression (LC) injuries (73.5%), with approximately half of these being LC1 injuries (38.2%). APC injuries were only seen in 5.9% of patients (6 patients: 3 APC2, 3 APC3), so these were grouped together for analysis (Supplementary Table 1). Thirteen patients had concurrent acetabular fractures, but there were no clear associations between these and any particular pelvic ring injury pattern or outcomes. Thirteen patients (12.7%) had open pelvic injuries.

The most common mechanism of injury was a fall from height (31.4%), with the majority of remaining injuries being caused by incidents involving vehicles. None of the patients in this study had a fragility fracture following a fall from standing height or low energy mechanism (Table 1).

All patients were managed initially with a pelvic binder and 54 patients (52.9%) had no other form of haemorrhage control intervention, either due to physiologic stabilisation or perceived futility. The remaining patients received a mixture of interventions including damage-control laparotomy with or without extra-peritoneal pelvic packing, other surgery (e.g. to address a chest injury or limb arterial injury), angio-embolisation with interventional radiology (IR) or REBOA, with some receiving more than one of these (Table 1).

For the patients that survived, median HLOS was 41.0 days (IQR 24.7–73.2), and median ICULOS was 8.5 days (IQR 0–17.5). The mean ISS was 41.4 (SD 16.5), reflecting that the majority of patients had severe injuries to other body regions (AIS ≥ 3), with the most commonly involved being the head (39 patients, 38.2%) and chest (61 patients, 59.8%) (Table 1).

Fifty-seven patients (55.9%) underwent pelvic surgical fixation, of which 30 patients (52.6%) had iliosacral screw fixation combined with INFIX application (anterior subcutaneous internal fixator) [23, 24] (Table 1). Median time from admission to fixation was 4.5 days (IQR 2.7–6.5), with 22 patients (38.6% of fixed patients) receiving fixation within 72 h. Patients that underwent fixation within 72 h had a shorter ICULOS (median 3.7 vs. 13.1 days, p = 0.032); however these patients also had lower ISS (mean 33.1 vs 43.5, p = 0.006). The early fixation group was also associated with lower arrival heart rate, PRBC and cryoprecipitate transfusion.

Mortality

Case notes were reviewed to determine the causes of death. Overall, 33 (32.4%) patients died during admission, after a median time from admission of 1.2 days (IQR 0.6 – 4.7). Of these, 16 (48.5%) were due to head injury. Five patients (15.2%) died as a result of a chest or abdominal injury, and only 2 patients (6.1%) died directly as a result of acute exsanguination (Table 2).

Ten patients (30.3%) died as a result of multiple organ dysfunction syndrome (MODS). These deaths often occurred following severe haemorrhagic shock and subsequent haemodynamic stabilisation. This group had a significantly higher PRBC transfusion requirement in the first 24 h compared with the remaining study population (median 14 vs. 5 units, $p = 0.001$). There were no significant differences in terms of arrival SBP, heart rate, lactate or BD. This group also had a significant association with LC3 injury pattern (40% vs 13%, $p = 0.048$) and were often burdened by severe soft tissue trauma (Table 2).

Multivariable logistic regression for mortality

All available patient demographics, injury classifications, treatments and outcome data were evaluated for association with mortality using univariate analysis. LC1 was used as the reference group for analysis of the other injury types. A significant ($p < 0.1$) positive association was found for

Table 2 Causes and timings of death

Category	*n* (%)	Subcategory	*n* (%)	LOS (days)	Notes
Mortality	33 (32.4%)*			Median 1.2 IQR 0.6–4.7	
Head Injury	16 (48.5%)	Unsurvivable head injury—early	11 (33.3%)	0.1, 0.1, 0.1, 0.6, 0.6, 0.6, 1.0, 1.1, 1.2, 1.4, 1.5	AIS Head = 5 (8 pts), 6 (1 pt), unknown for 2 pts (no CT scan)
		Later deterioration	5 (15.2%)	3.8, 4.7, 5.2, 8.6, 11.8	AIS Head = 5 (4 pts), 4 (1 pt)
Multiple Organ Dysfunction	10 (30.3%)	Elderly polytrauma (age > 65)	4 (12.1%)	2.3, 3.7, 5.1, 20.0	Pt 1: Extensive chest + abdominal injuries (ISS 75, age 67, Pelvic injury: LC3, HCI: Laparotomy, SBP: N/A, BD: 11.7, PRBC: 12) Pt 2: Extensive soft tissue injury (ISS 33, age 76, Pelvic injury: LC2, HCI: None, SBP: 86, BD: 7.9, PRBC: 11) Pt 3: Extensive soft tissue and bowel injuries (ISS 59, age 73, Pelvic injury: SPD, HCI: REBOA, Laparotomy + IR, SBP: 83, BD: 9.9, PRBC: 21) Pt 4: Deterioration of existing condition, multiple injuries (ISS 41, age 80, Pelvic injury: Combined, HCI: IR, SBP: 62, BD: 2.6, PRBC: 7)
		Polytrauma	1 (3.0%)	1.2	Head, chest and abdominal injuries (ISS 66, age 53, Pelvic injury: LC1, HCI: REBOA + Laparotomy, SBP: 58, BD: N/A, PRBC: 18)
		Extensive soft tissue injury	3 (9.1%)	4.7, 8.4, 8.4	Pt 1: Crush injuries to legs, deterioration despite bilateral above knee amputations (ISS 50, age 24, Pelvic injury: LC3, HCI: Laparotomy, SBP: N/A, BD: N/A, PRBC: 64) Pt 2: Extensive soft tissue injury to legs and pelvis (ISS 33, age 51, Pelvic injury: LC3, HCI: Laparotomy, SBP: N/A, BD: 31.6, PRBC: 36) Pt 3: Soft tissue injuries to legs, deterioration despite bilateral through knee amputations (ISS 33, age 48, Pelvic injury: LC1, HCI: REBOA + Laparotomy, SBP: 86, BD: N/A, PRBC: 16)

Table 2 (continued)

Category	*n* (%)	Subcategory	*n* (%)	LOS (days)	Notes
		Other	2 (6.1%)	1.1, 2.8	Pt 1: Exsanguination due to deliberate self-harm (laceration) prior to jumping from height (ISS 45, age 34, Pelvic injury: LC3, HCI: None, SBP: 40, BD: N/A, PRBC: 8) Pt 2: Suspected fat embolus after bilateral femoral nails (ISS 13, age 50, Pelvic injury: SPD, HCI: None, SBP: 118, BD: 1.5, PRBC: 6)
Chest or Abdominal Injury	5 (15.2%)	Early	4 (12.1%)	0, 0.01, 0.05, 0.07	Pt 1: Unsurvivable chest injury Pt 2: Abdominal arterial injury Pts 3 + 4: Extensive chest + abdominal injuries
		Late	1 (3.0%)	34.9	Abdominal injury, 3 laparotomies, suspected liver failure
Pelvic Exsanguination	2 (6.1%)	Patient 1	1 (3.0%)	0	Haemodynamic instability due to iliac artery injury, concurrent chest, abdominal and spinal injuries. Decision to palliate on arrival (ISS 57, age 73)
		Patient 2	1 (3.0%)	1.0	Associated chest, abdominal and spinal injuries, and significant pelvic haematoma. PEA cardiac arrest with no other evident source of bleeding

LOS: Length of stay, *AIS*: Abbreviated injury scale, *pt*: Patient, *HCI*: Haemorrhage control intervention (None = pelvic binder only), *SBP*: Systolic blood pressure on arrival (mmHg), *BD*: Base deficit on arrival (mmol/l), *PRBC*: Packed red blood cells (units) transfused in first 24 h, *N/A*: Not available

*Overall mortality expressed as a percentage of whole study population. All remaining values expressed as percentage of mortalities

Age, ISS, AIS Head ≥ 3, AIS Chest ≥ 3, Open Fracture and Laparotomy, and a negative association with IR and SBP (Table 3).

Separate multivariable models were created for each of ISS, AIS Head and AIS Chest as they are colinear. None of the models with AIS Chest, SBP or Laparotomy as variables remained statistically significant. ISS, AIS Head, Age and Open Fracture all remained statistically significant independent positive predictors of mortality, and IR was predictive of reduced mortality ($p < 0.05$) (Table 3).

Associations with injury type

There was a significant association between Vertical Shear injuries and requirement for haemorrhage control intervention (OR 10.7, $p = 0.036$). All patients with Anterior Posterior Compression 3 (APC3) and Combined injury patterns required haemorrhage control interventions, but this finding lacked statistical significance due to small sample size. There were no statistically significant associations between any of the other injury patterns and haemorrhage control interventions (Supplementary Table 1).

APC3 injuries were significantly more likely to be open fractures than the other injury types (OR 24.0, $p = 0.020$). On evaluation of LC injuries separately, LC3 injuries were significantly more likely to be open fractures (LC3: 25%, LC1: 7.7%, LC2: 0%, $p = 0.042$). There were no statistically significant associations between injury type and HLOS, ICULOS, or ISS.

Patients that did *not* undergo pelvic fixation were further evaluated and their management categorised as either intentionally non-operative (i.e. pelvic injury documented by the treating pelvic surgeon as stable–18 patients, 17.6%), or having died of other causes prior to the opportunity for fixation (unstable injuries which would have warranted surgery–27 patients, 26.5%). Non-LC1 injury types were significantly more likely to require operative fixation than LC1 injuries ($p=0.001$) (Supplementary Table 1).

Discussion

This study describes a population of trauma patients with pelvic ring injuries who were admitted with features of haemorrhagic shock. We found that mortality was predicted by increasing age, ISS, severe head injury, and open fractures, which is in line with previous studies [11, 17]. Additionally, undergoing angio-embolisation (interventional radiology) was associated with reduced mortality, which confirms that it can be a valuable life-saving intervention when used appropriately in patients with arterial bleeding [25].

A series of studies at a high volume centre evaluated patients with haemodynamically unstable pelvic fractures [12, 13, 17, 19], and demonstrated mortality rates falling from 26% in 1998–2004 [17] to 14% in 2015–2019 [13], reflecting improvements in care including the implementation of pre-peritoneal packing and subsequently REBOA. However, the patient selection criteria for these studies may account for differences with our results. For example, these studies included patients that had received at least one unit of PRBC [17], or surgical intervention after two units of PRBC [12, 13, 19], which may have also excluded patients with severe concurrent injuries, such as unsurvivable head injuries. Our cohort included all patients with pelvic fractures and features of haemorrhagic shock, irrespective of interventions performed or concurrent injuries.

A contemporary study conducted at 3 regional trauma centres in Korea reported a cohort of 157 patients with pelvic injury and haemodynamic instability. Patient demographics and admission haemodynamic parameters were comparable to our study, with mean ISS of 39.1, mean SBP of 86.7 mmHg, and mean lactate of 6.68 mmol/l (in our study these were 41.4, 84.9 mmHg and 5.52 mmol/l, respectively). They reported a 46.5% mortality, of which over half (54.8%) was due to acute haemorrhage [6].

In our study, the overall mortality rate was 32.4%, which is comparable to other studies of haemodynamic instability in pelvic fractures [4, 7]. Historically, haemodynamically unstable pelvic fractures have been associated with a higher mortality rate than this [8], but outcomes have improved over the last twenty years as a result of damage control resuscitation, access to interventional radiology, massive transfusion protocols and local Emergency Department (ED) and ICU expertise, which are now ubiquitous within developed trauma systems [14, 26].

Whilst bleeding was implicated in 36.4% of deaths in our population, only 6.1% of patients died from uncontrolled pelvic exsanguination which suggests that measures aimed at haemorrhage control are impactful on the initial outcomes of resuscitation. Instead, death is now more commonly caused by MODS (30.3%)–whether aetiologically attributable to haemorrhagic shock [27] or the combined effect of other severe injuries [28], most commonly head injuries (48.5%) or chest or abdominal injuries (15.2%) in our cohort (Table 2). MODS is generally characterised by systemic inflammatory response syndrome (SIRS) and delayed (> 24 h after admission) decline in metabolic parameters despite achieving haemodynamic stability. This pathophysiology of post-traumatic inflammation is not well understood, although it is recognised that the severity of initial bleeding and diminished tissue perfusion, as marked by haemodynamic instability [27] and increased requirement for blood product transfusion, is related to subsequent development of SIRS/MODS. This is an interesting area for further research as mortality may be further reduced in the future if these inflammatory processes can be better understood and treated.

Our results demonstrated that patients undergoing early pelvic fixation (within 72 h of admission) tended to have shorter stays on ICU (median 3.7 vs. 13.1 days, $p=0.032$), but this group of patients also had significantly lower ISS and transfusion requirements, highlighting that the timing of definitive fixation is often dictated by other factors.

The limitations of this study include the fact that it was retrospective, which may have made it more susceptible to information bias. In addition, the numbers in this study were relatively small for some of the pelvic classification groups (APC/VS/Combined/SPD), which makes it difficult to draw statistically meaningful conclusions, e.g. although there was a trend towards increased haemorrhage control interventions for APC and Combined injuries [5, 29], this association only reached statistical significance for the vertical shear injuries.

Changes to institutional protocols and resuscitation setup is also a potential source of bias. Fortunately, the ED protocols, building setup and training and staffing with respect to seniority of clinical leaders and decision-makers during this period were stable. However, REBOA was an emerging technology during this time and so there may have been a 'learning curve' associated with its use that has influenced our results [2, 30]. REBOA has been proven to be an effective method for temporarily taking control of haemorrhage [13, 31, 32]. However, some studies have reported that it may be associated with an increased risk of mortality [33, 34], stressing the need for further work in this area.

It was pragmatic to include all patients that had signs of haemorrhagic shock at presentation, where the sources of bleeding were characterised later, which reflects the clinical pathway of patients in our healthcare system. We have made the assumption that pelvic bleeding was a significant contributor to the shock seen in all patients but this will not

Table 3 Multivariable logistic regression for variables predicting mortality

Univariate Analysis		
Variable	Odds ratio	*p* value
Age	**1.023**	**0.068***
Gender (female)	1.905	0.140
ISS	**1.069**	**< 0.001***
AIS head ≥ 3	**2.270**	**0.059***
AIS chest ≥ 3	**2.306**	**0.069***
AIS abdomen ≥ 3	1.988	0.129
AIS spine ≥ 3	0.727	0.611
AIS pelvis & lower extremity ≥ 3	1.750	0.501
LC1	2.051	0.118
LC2	0.506	0.182
LC3	0.557	0.293
APC (2 or 3)	2.200	0.351
VS	2.264e + 7	0.991
Combined	0.705	0.709
SPD	0.952	0.948
Open Fracture	**4.096**	**0.022***
SBP on arrival	**0.985**	**0.097***
BD on arrival	0.951	0.193
HR on arrival	1.004	0.527
Haemorrhage control intervention (any)	1.302	0.533
Laparotomy	**2.895**	**0.021***
IR	**0.214**	**0.049***
REBOA	2.844	0.106
Fixation within 72 h	1.067	0.946
Multivariable Models		
Model 1–ISS		
(χ2 (83) = 4.534, p = 0.033, 78.4% accuracy)		
ISS	1.081	< 0.001*
Age	1.040	0.018*
IR	0.101	0.031*
Open fracture	7.622	0.043*
Model 2–AIS head		
(χ2 (84) = 5.944, p = 0.015, 73.9% accuracy)		
AIS Head ≥ 3	7.866	< 0.001*
Age	1.039	0.016*
Open Fracture	8.034	0.018*

Patient demographics, injury classifications, treatments and outcome data were evaluated for association with mortality, with a threshold of $p < 0.1$ (shown in bold) for inclusion in multivariable models

Separate multivariable models were created for each of ISS, AIS Head and AIS Chest as they are colinear. None of the models with AIS Chest, SBP or Laparotomy as variables remained statistically significant

ISS, AIS Head, Age and Open Fracture all remained statistically significant independent positive predictors of mortality, and IR was predictive of reduced mortality (*$p < 0.05$)

have been true for some. We were not able to quantify blood loss specifically attributable to the pelvis for each case.

Conclusion

Haemodynamic instability on admission, in association with pelvic ring injuries, remains a challenge for trauma teams and carries a significant mortality risk. Mortality was predicted by increasing age, ISS, severe head injury, and open fractures. In our study, whilst bleeding was implicated in 36.4% of deaths, very few patients died from acute exsanguination, and undergoing angio-embolisation with interventional radiology was associated with reduced mortality. This reflects the beneficial effects of a nationally structured trauma network system that results in coordinated pre-hospital care, local multidisciplinary expertise and safe implementation of innovations within resuscitative care, including transfusion protocols, and haemorrhage control techniques.

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Declarations

Conflict of interest The authors have no competing interests to declare that are relevant to the content of this article.

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