Injury 53 (2022) 4054–4061

Contents lists available at ScienceDirect

Injury

journal homepage: www.elsevier.com/locate/injury

Management of high-energy blunt pelvic ring injuries: A retrospective cohort study evaluating an institutional protocol

Silvia Valisena[a,*], Anna-Eliane Abboud[a], Elisabeth Andereggen[b], Alexandre Ansorge[a], Axel Gamulin[a]

[a] *Division of Orthopaedic and Trauma Surgery, University Hospitals of Geneva, 4 Rue Gabrielle-Perret-Gentil, CH-1205 Geneva, Switzerland*
[b] *Division of Emergency Medicine, University Hospitals of Geneva, 4 Rue Gabrielle-Perret-Gentil, CH-1205 Geneva, Switzerland*

ARTICLE INFO

Article history:
Accepted 16 September 2022

Keywords:
High-energy pelvic ring injury
High-energy blunt trauma
Hemodynamic instability
Hemorrhage control
Polytrauma

ABSTRACT

Introduction: High-energy blunt pelvic ring injuries with hemodynamic instability are complicated by a high mortality rate (up to 32%). There is no consensus on the best management strategy for these injuries. The aim of this study was to evaluate the high-energy blunt pelvic ring injury management protocol implemented in the authors' institution.
Patients and Methods: This retrospective cohort study was performed in an academic level I trauma center. The institutional protocol incorporates urgent pelvic mechanical stabilization of hemodynamically unstable patients not responding to a pelvic belt, fluids, and transfusions. If hemodynamic instability persists, angiography ± embolization is performed. Adult patients sustaining a high-energy blunt pelvic ring injury between 2014.01.01 and 2019.12.31 were included in the study. The primary outcome was mortality at 1, 2, 30 and 60 days. The secondary outcomes were the number of packed red blood cell units transfused during the first 24 h, intensive care unit stay, and total hospitalization length of stay.
Results: 192 high-energy blunt pelvic ring injury patients were analyzed. Of these, 71 (37%) were hemodynamically unstable, and 121 (63%) were stable. The overall in-hospital mortality of the hemodynamically unstable and stable groups was 20/71 (28.2%) and 4/121 (3.3%) respectively (p<0.001). Cumulative mortality rates for hemodynamically unstable patients were 15.5% at day 1, 16.9% at day 2, 26.8% at day 30 and 28.2% at day 60, and for hemodynamically stable patients, rates were 0% at day 1 and 2, 2.5% at day 30 and 3.3% at day 60. Unstable patients required a higher number of packed red blood cell units than stable patients during the first 24 h (5.1 vs. 0.1; p<0.001). Intensive care unit length of stay and total hospitalization duration was 11.25 and 37.4 days for unstable patients and 1.9 and 20.9 days for stable patients (p<0.001).
Conclusions: For both hemodynamically unstable and stable patients, the institutional protocol showed favorable mortality rates when compared to available literature. Comparative studies are needed to determine the management strategies with the best clinical outcome and survival.

Introduction

The management of high-energy trauma patients with pelvic ring injury (PRI) is a challenge in trauma care, as this condition can be associated with multiple systemic lesions and hemodynamic instability, and complicated by high mortality and morbidity [1]. Patients admitted to the Emergency Department (ED) in shock have the poorest prognosis, with reported mortality rates reaching 32% [2–5]. Therefore, one of the main goals in trauma care is to reduce mortality in hemodynamically unstable PRI patients.

Current literature shows a remarkable evolution of hemodynamically unstable PRI management protocols in the last decades, with historical milestones represented by the introduction of angioembolization in the 1970s [6], followed by pelvic packing techniques in the 1980s [7,8], and finally resuscitative endovascular ballooning of the aorta (REBOA) for *in extremis* management of hemodynamically unstable PRI patients [9]. This evolution was supported by research on the origin of pelvic sources of bleeding - in 80–90% of hemodynamically unstable PRI, the main sources of bleeding are the presacral and paravesical venous plexi, and the bone [10]. In the remaining 10–20%, the source of bleeding is ar-

* Corresponding author.
E-mail addresses: silvia.valisena@gmail.com, silvia.valisena@hcuge.ch (S. Valisena).

https://doi.org/10.1016/j.injury.2022.09.020

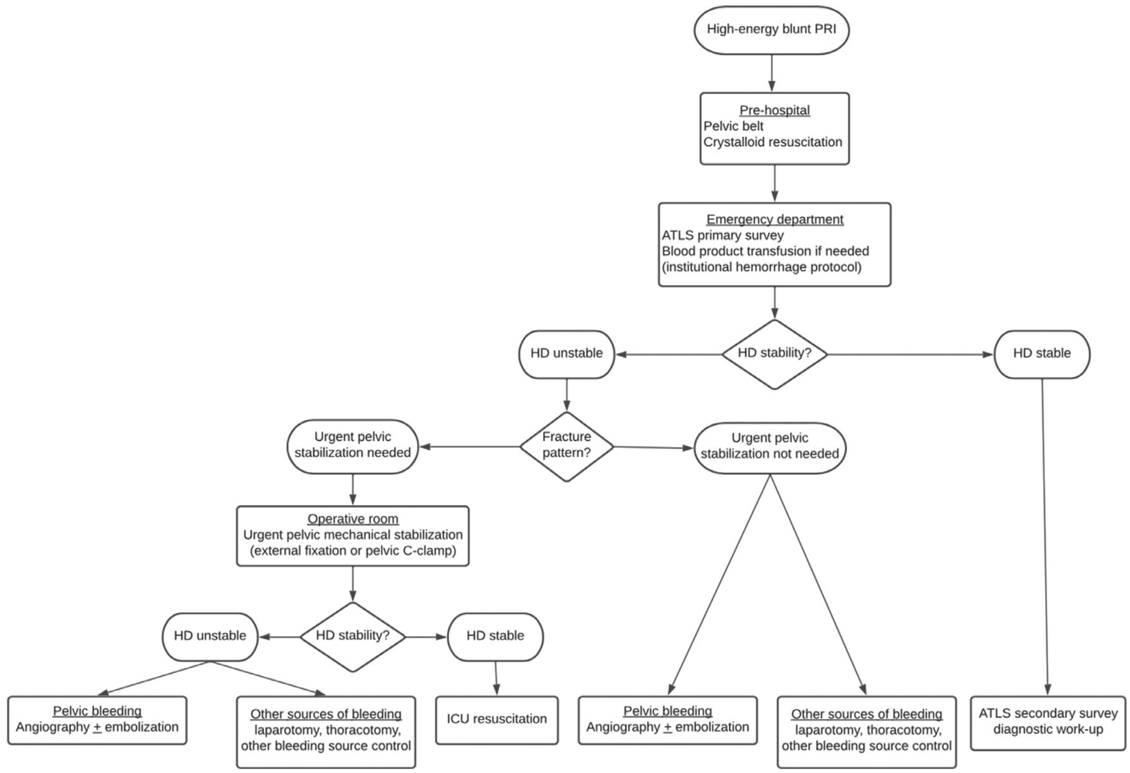

Fig. 1. Description of the institutional high-energy blunt PRI management protocol.ATLS: advanced trauma life support; HD: hemodynamically/hemodynamic; ICU: intensive care unit; PRI: pelvic ring injury.

terial, mainly from the branches of the internal iliac artery [10,11]. Due to the multiple possible sites of bleeding in hemodynamically unstable polytrauma patients, radiological signs of pelvic bleeding such as free liquid in the abdominal cavity on Focused Assessment with Sonography for Trauma (FAST), or pelvic hematoma and blush sign on computed tomography (CT) scan are relevant to guide resuscitative management [12,13]. Evidence of the blush sign is an indication for angiography and therapeutic embolization in both hemodynamically stable and unstable patients in many centers [4]. Since arterial bleeding is often accompanied by major venous bleeding, some algorithms approach pelvic hematoma with pelvic packing in addition to, or as an alternative to, temporary mechanical fixation, resorting to angioembolization only in cases of persistent hemodynamic instability [4,14,15]. Despite the vast literature on the management of hemodynamically unstable high-energy trauma patients with PRI, there is no consensus on the best strategy to decrease mortality and morbidity [1,16]. A contributing factor to this heterogeneity is the variable availability and stewardship of resources in each trauma center [4,16].

In the authors' institution, a standardized management protocol for high-energy blunt PRI, differentiating hemodynamically stable and unstable patients, has been implemented since 2000 [17,18]. The aim of the present study is to evaluate the outcome of this management protocol.

Materials and methods

Study design

This retrospective cohort study was performed in a tertiary center meeting all the requirements of a level I trauma center as defined by international and national medical authorities [19,20]. The local research ethics committee approved the study protocol. There was no external source of funding or financial support for this study.

Institutional high-energy blunt PRI management protocol (Fig. 1)

In the case of a suspected PRI, a pelvic belt [21] is applied at the accident site (sometimes later in the ED), and crystalloid resuscitation is started simultenaously by the prehospital team. Upon ED admission, Advanced Trauma Life Support (ATLS) [22] primary survey is performed with FAST, and, when the patient's condition allows, with an additional total-body CT scan including vascular (arterial and venous) sequences. Blood transfusion is started when necessary, following the institutional hemorrhage protocol, consisting of 5 PRBC, 5 fresh-frozen plasma units and 5 platelet concentrates. Further blood product transfusion may be administered according to the patient's needs. Hemodynamically unstable patients (defined by systolic blood pressure $<$90 mmHg and/or heart rate $>$100 bpm) not responding to a pelvic belt, fluids and transfusions, with a mechanically unstable PRI justifying stabilization, undergo urgent pelvic mechanical stabilization in the operative room (OR), using either external fixation [23–25] or pelvic C-clamp [26] according to the injury pattern. The analysis of pelvic mechanical stability and the decision to perform urgent pelvic mechanical stabilization are made by the attending orthopedic trauma surgeon on the basis of an intra-pelvic volume increase due to a type B or C PRI according to AO/OTA classification [27]. Plain pelvis anteroposterior radiographs and pelvic CT-scan images are used for this purpose. The rationale for making this step first is to rapidly restore the pelvic volume by means of mechanical stabilization, increasing the intra-pelvic pressure above the central venous pressure and controlling the low-pressure venous and osseous bleeding [18,26,28]. If hemodynamic instability persists, and if there is no other extra-pelvic source of bleeding (such as hemothorax, intra-abdominal bleeding, external bleeding), angiography is performed to look for potential associated arterial bleeding, and selective embolization is eventually carried out. Non-responders to fluid resuscitation with a mechanically stable pelvic fracture undergo angiography to diagnose the potential source of bleeding and eventually embolization. Of note, angioembolization is available within one hour in the authors' institution, on a 24/7 basis, in a dedicated suite separated from the operating theater: thus, patients need to be moved to the angioembolization suite after pelvic mechanical stabilization in the OR. Also, pelvic packing is not performed in our institution. This protocol is applied to every high-energy PRI patient, irrespectively of other concomitant injuries. For example, patients with an associated life-threatening traumatic brain injury are managed concomitantly, in parallel to the PRI management (intra-cranial pressure monitoring, trepanation and drainage, partial craniectomy).

Hemodynamically stable patients undergo a secondary ATLS survey and diagnostic work-up, and emergency or delayed pelvic stabilization when needed as indicated by the injury pattern. Finally, hemodynamically stable patients may be brought to angioembolization if their CT scan shows a blush sign.

Study population

High-energy trauma patients' data are prospectively recorded since mid-2013 in the institutional *severely injured patients' registry* (SIPR). The SIPR was screened for high-energy blunt PRI patients meeting the following inclusion criteria: 1) high-energy blunt PRI, defined as closed fracture of the pelvic ring following road traffic accidents, sport injuries, crush, farm and industrial injuries and falls from a height >1 m, as reported by the prehospital team; 2) admissions between 2014.01.01 and 2019.12.31; and 3) age ≥16 years at admission. Exclusion criteria were: 1) death before ED admission; 2) secondary transfer after initial treatment in another institution; and 3) institutional protocol not followed.

Variables of interest

Demographic data (age, gender, mechanism of injury), clinical data (pre-hospital and ED systolic blood pressure and heart rate), therapeutic data (total number of packed red blood cells (PRBC) transfused during the first 24 h), outcome data (survival or death, complications, intensive care unit (ICU) and total hospitalization length of stay excluding rehabilitation) and injury severity scores (ISS) [29,30] were retrospectively extracted from the SIPR. Three board-certified orthopedic surgeons consensually performed complete AO/OTA [27] and Young and Burgess [31] classifications.

For analysis purpose, PRI classifications were simplified to the main types (AO/OTA type A, B or C and Young and Burgess type lateral compression, anteroposterior compression, vertical shear or combined mechanism). Patients were considered hemodynamically unstable when pre-hospital or ED systolic blood pressure was <90 mmHg and/or heart rate was >100 bpm; they were otherwise considered hemodynamically stable. 'Complication' was defined as any condition appearing during hospitalization and worsening the outcome, such as wound issues, acute compartment syndrome, infection, decubitus ulcer, thrombo-embolism, organ failure, myocardial infarct, stroke, and cardiorespiratory arrest [32]. Current literature defines polytrauma by an ISS ≥16 [33,34] whereas studies on high-energy PRI often show a related ISS ≥25 [1]. For this reason, ISS was stratified into three categories: ISS ≤15, 16≤ ISS ≤24, and ISS ≥25.

Outcomes

The primary outcome was mortality. The literature reports that most early deaths occur at day 1, marking the threshold for the definition of early mortality [35]. In addition to day 1 (early) mortality, cumulative day 2, 30 and 60 mortality rates were also considered. Secondary outcomes were the number of PRBC transfused during the first 24 h, as well as ICU stay and total hospitalization length of stay.

Statistical analysis

Continuous variables were expressed as means ± standard deviations, medians and interquartiles 1–3 (IQ 1–3). Categorical variables were expressed as absolute counts and relative proportions.

The ISS was expressed as mean ± standard deviation and range. For each variable, the *p*-value was calculated when feasible. Comparisons of continuous variables were conducted using the Welch *t*-test. Comparisons of categorical variables were conducted using Chi squared, or Fisher's exact test when appropriate. Only complete case analyses were performed (there were no missing data imputations). Data analyses were conducted using R 4.0.2 (The R Foundation for Statistical Computing, Vienna, Austria. URL https://www.R-project.org). Statistical significance was defined as $p<0.05$.

Results

A consecutive series of 195 high-energy blunt PRI patients was identified from the SIPR. Among these patients, 192 met the eligibility criteria and 3 were excluded. In two of them the initial management was performed in another hospital. In the third patient, mechanical pelvic stabilization and angio-embolization were performed in the opposite sequence for an unknown reason. Patients' demographic and injury characteristics are available in a dedicated repository and described in a separate publication [36].

Among the 192 patients included in the final analysis, 71 (37%) were hemodynamically unstable and 121 (63%) were stable. Table 1 compares the clinical and radiological data of the hemodynamically unstable and stable patients.

Early (day 1) mortality was significantly higher for hemodynamically unstable patients (15.5% vs. 0% for stable patients), as well as cumulative day 2 (16.9% vs. 0%), day 30 (26.8% vs. 2.5%) and day 60 (28.2% vs. 3.3%) mortality (Table 1). Fig. 2 shows the detailed results of each step of management of the institutional high-energy blunt PRI protocol in terms of mortality. Of note, no embolization, nor urgent pelvic stabilization was performed within the 121 hemodynamically stable patients. In the hemodynamically unstable group, 26/71 (37%) responded to fluid resuscitation and 45/71 (63%) were still hemodynamically unstable. Among these 45 patients, 10 died before any procedure could be performed. Of the remaining 35 patients, angioembolization alone was performed on 3 initially hemodynamically unstable patients with a fracture not requiring urgent stabilization (described in Table 2), with success on achieving hemodynamical stability. Hemodynamically unstable patients presenting an unstable fracture not responding to fluid resuscitation (32/35) underwent urgent pelvic stabilization by external fixation in 23 cases and pelvic C-clamp in nine cases, achieving hemodynamic stabilization in 28/32 (88%) and requiring further angioembolization in 4/32 (12%).

Time to urgent pelvic mechanical stabilization is presented for the 32 hemodynamically unstable patients in Fig. 2 and Table 2: mean time was 216 +/- 116 min (range 60- 652). Time to angioembolization (seven cases) is presented in Table 2: the four hemodynamically unstable patients requiring both urgent pelvic stabilization and angioembolization underwent embolization 50 +/- 47 min after the end of surgery (minimum 20, maximum 120). Table 2 also presents the fracture patterns and embolized arteries of the seven hemodynamically unstable patients requiring angioembolization. Among the 32 patients who underwent urgent fixation, 27 underwent definitive pelvic fixation after urgent pelvic

Table 1
Description of the 192 study patients.

Variables	Hemodynamically stable patients (*n* = 121, 63.0%)	Hemodynamically unstable patients (*n* = 71, 37.0%)	*p*-value
Age in years	44.2 (±18.8, 42, 27–55)	46.6 (±19.1, 48, 29–62)	0.390
Male sex, n (%)	63 (52.1)	43 (60.6)	0.321
Injury mechanism, n (%)			0.293[1]
Car crash	5 (4.1)	8 (11.3)	
Motorbike crash	21 (17.4)	16 (22.5)	
Bicycle crash	7 (5.8)	2 (2.8)	
Pedestrian traffic accident	29 (24)	12 (16.9)	
Fall from height >1 m	53 (43.8)	30 (42.3)	
Crush, farm, industrial accident	4 (3.3)	2 (2.8)	
Sports accident	2 (1.7)	0 (0)	
Unknown	0 (0)	1 (1.4)	
AO/OTA classification, n (%)			<0.001
Type A	30 (24.8)	8 (11.3)	
Type B	84 (69.4)	39 (54.9)	
Type C	7 (5.8)	24 (33.8)	
Young and Burgess classification, n (%)			<0.001[1]
Lateral compression	78 (64.5)	34 (47.9)	
Anteroposterior compression	6 (5)	17 (23.9)	
Vertical shear	1 (0.8)	1 (1.4)	
Combined mechanism	7 (5.8)	12 (16.9)	
Not classifiable	29 (24)	7 (9.9)	
ISS, mean (±SD, range)	20.2 (±9.0, 4–45)	35.3 (±14.4, 9–66)	<0.001
ISS categorized, n (%)			<0.001
≤15	34 (28.1)	2 (2.8)	
16≤ ISS ≤24	56 (46.3)	17 (23.9)	
≥25	31 (25.6)	52 (73.2)	
Patients needing PRBC within first 24 h, n (%)	6 (5.0)	48 (67.6)	<0.001
PRBC units received within first 24 h	0.1 (±0.5, 0, 0–0)	5.1 (±8.5, 2.5, 0–6)	<0.001
Patients needing ICU, n (%)	48 (39.7)	54 (76.1)	<0.001
ICU length of stay in days	1.9 (±3.5, 0, 0–2)	11.2 (±14.1, 7, 1–14.5)	<0.001
Total hospitalization duration in days	21.0 (±24.5, 14, 8–23)	39.9 (±40.6, 26, 9–56)	<0.001
Patients presenting complications, n (%)	27 (22.3)	31 (43.7)	0.003
Overall mortality at Day 60, n (%)	4 (3.3)	20 (28.2)	<0.001
Cumulative mortality, n (%)			–
Day 1 (early mortality)	0 (0)	11 (15.5)	
Day 2	0 (0)	12 (16.9)	
Day 30	3 (2.5)	19 (26.8)	
Day 60	4 (3.3)	20 (28.2)	
Day 2 to 60 (late mortality)	4 (3.3)	9 (12.7)	0.098[1]
Time to death in days, mean (±SD)	22.3 (±20. 6)	8.5 (±12.9)	0.275
Overall mortality in the whole population, n (%)	24 (12.5)		

Continuous variables are expressed as mean (±SD, median, IQ1–3), unless notified otherwise. *P*-values were obtained using Welch *t*-test and Chi squared, or [1]Fischer's exact test.
PRI classifications were simplified to the main types: AO/OTA type A, B and C, and Young and Burgess type lateral compression, antero-posterior compression, vertical shear and combined mechanism.
ICU: intensive care unit. *IQ1–3:* interquartile 1–3. *ISS:* injury severity score. *PRBC:* packed red blood cells. *SD:* standard deviation.

fixation at mean 7 days (range 2–22 days), and 5 died before any definitive fixation could be done (Fig. 2).

Table 3 explores factors associated with mortality in hemodynamically unstable patients. Except for higher ISS, higher number of PRBC transfused within the first 24 h and shorter total hospitalization duration, non-survivors did not differ from survivors.

Hemodynamically unstable patients required PRBC transfusion more often (67.6% vs. 5%), and in larger amounts (5.1 vs. 0.1 units) than hemodynamically stable patients (Table 1). Hemodynamically unstable patients needed ICU management more often (76.1% vs. 39.7%), and for a longer time (11.2 vs. 1.9 day) than hemodynamically stable patients, and they also had a longer total hospitalization duration (39.9 vs. 21.0 days) (Table 1).

Discussion

We evaluated the outcomes of our institutional management protocol for high-energy blunt PRI patients. Early (day 1) mortality in hemodynamically unstable patients was 15.5%, day 2 to day 60 mortality was 12.7% and cumulative 60-day mortality 28.2%. When also considering hemodynamically stable patients (cumulative 60-day mortality 3.3%), global in-hospital mortality was 12.5% for high-energy blunt PRI patients.

Comparable mortality rates were reported in a study using a management protocol similar to ours: Jeske et al. found a 76% survival rate within the first 24 h and an overall 67% in-hospital survival rate amongst 45 hemodynamically unstable PRI patients [37]. Similarly, Metsemakers et al. found an overall in-hospital mortality of 20% on a sample of 15 hemodynamically unstable patients treated with emergent pelvic fixation, followed by angioembolization for persistent hemodynamical instability [38]. By contrast, recent multi-center studies performed in the USA including different management protocols reported a mortality rate reaching 32% among high-energy blunt PRI patients with hemodynamic instability [4,39,40]. Among the evaluated protocols, mortality was higher for those who underwent REBOA ± other treatment (69% of 13 patients). Most patients (97) only received a pelvic binder with a mortality of 26%, and there was no mortality in the patients stabilized with external fixation (8 patients) [40]. In comparison, the results of the protocol in use at our institution are encouraging, with 15.5% early and 12.7% delayed mortality in hemodynamically unstable patients, however, the small sample size of both our study and aforementioned studies by Jeske et al. and Metsemakers et al.

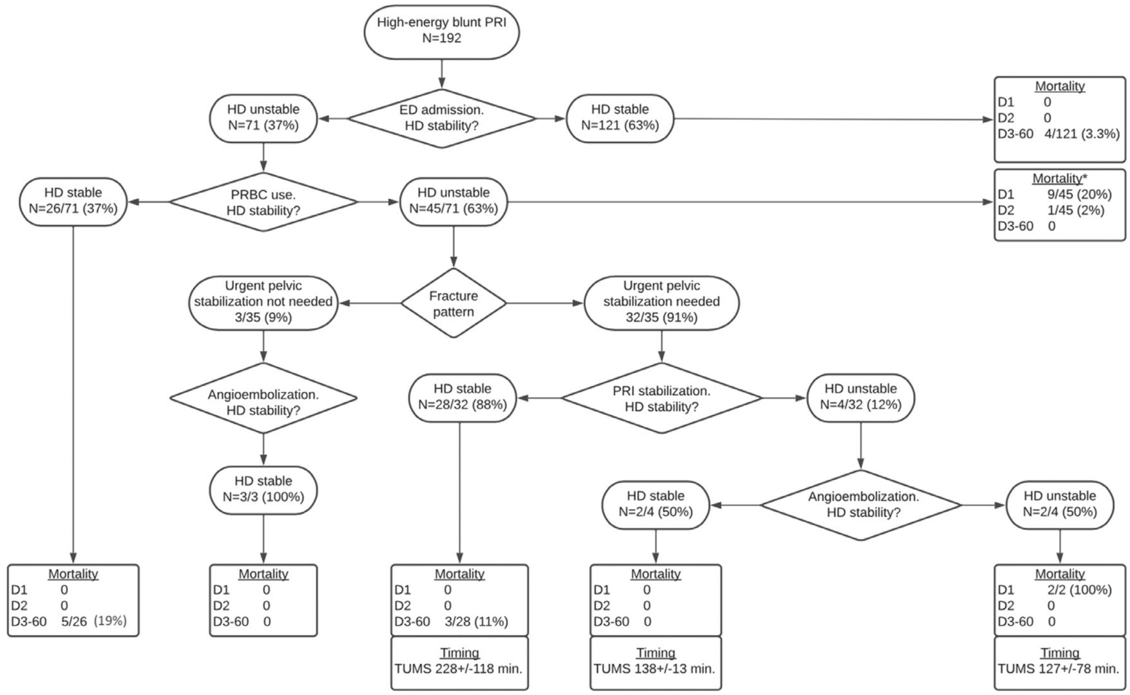

Fig. 2. Detailed results of each step of management of the institutional high-energy blunt PRI protocol in terms of mortality.No embolization was performed within the 121 hemodynamically stable patients' group. There was no occurrence of embolization on initially hemodynamically unstable patients which were stabilized with either PRBC transfusion or PRI stabilization.* Among the 45 non-responders to fluid resuscitation, nine immediately died and 1 was not suitable for surgery due to very severe lesions and died at day 2.D: day; ED: emergency department; HD: hemodynamically/hemodynamic; min.: minutes; PRBC: packed red blood cells; PRI: pelvic ring injury; TUMS: time to urgent pelvic mechanical stabilization expressed in minutes, mean +/-SD.

Table 2
Description of pelvic ring injury, management timing, embolization and outcome of hemodynamically unstable patients requiring angioembolization.

Patient number	Pelvic ring injury classification		Time to pelvic stabilization		Time to angioembolization		Angioembolization description	Survival
	AO/OTA	Young and Burgess	Start	End	After pelvic stabilization	From admission		
6	C1	CM	72	59	27	158	Selective (Rt cystic a.)	No
41	C3	CM	148	20	34	142	Selective & non-selective (Lt superior gluteal a. & Rt internal iliac a.)	Yes
113	C2	APC3	182	75	20	277	Selective (Rt pudendal, lateral sacral, iliolumbar and superior gluteal aa.)	No
119	B2	APC2	129	81	120	330	Selective (Rt obturator a.)	Yes
9	B1	LC1	–	–	–	1625	Selective (Rt superior gluteal a.)	Yes
98	C3	CM	–	–	–	146	Selective (anterior trunk of Lt internal iliac a.)	Yes
160	B2	LC1	–	–	–	74	Selective (Lt superior gluteal a.)	Yes

Patients number 6, 41, 113 and 119 had urgent pelvic mechanical stabilization prior to angioembolization.
Patients number 9, 98 and 160 had pelvic injuries not requiring urgent mechanical stabilization and had angioembolization followed by either delayed pelvic stabilization or conservative treatment.
Patient 9: 68-year-old female with a PRI AO/OTA 61B1.1, Young & Burgess LC1 and concomitant vertebral lesions. Pelvic definitive treatment was conservative.
Patient 98: 52-year-old female with a PRI AO/OTA 61C3.3, Young & Burgess CM corresponding to a spinopelvic dissociation. Definitive spinopelvic fixation was performed on day 1.
Patient 160: 49-year-old female with a PRI AO/OTA 61B2.1b,e, Young & Burgess LC1, and left acetabular fracture. Definitive PRI and acetabular fracture fixation were performed on day 4, by supra-pectineal plate and sacroiliac screw.
AO/OTA classifications are described up to the group level, and Young and Burgess classifications are fully described.
Times are expressed in minutes.
Time to start urgent pelvic mechanical stabilization is obtained from admission.
Time to end of urgent pelvic mechanical stabilization is obtained from the start of the procedure and may include other urgent surgeries.
Time to angioembolization is obtained from the end of pelvic stabilization when applicable, and from admission.
CM: combined mechanism. *APC:* anteroposterior compression. *LC:* lateral compression. *Rt:* right. *Lt:* left. *a:* artery. *aa:* arteries.

Table 3
Comparison between hemodynamically unstable patients who did and did not survive.

Variables	Non-survivors(n = 20, 28.2%)	Survivors(n = 51, 71.8%)	p-value
Age in years	48.5 (±21.5, 51, 29–68)	45.9 (±18.3, 48, 29–57)	0.631
Male sex, n (%)	12 (60)	31 (60.8)	0.999
Injury mechanism, n (%)			0.221[1]
Car crash	1 (5)	7 (13.7)	
Motorbike crash	3 (15)	13 (25.5)	
Bicycle crash	1 (5)	1 (2)	
Pedestrian traffic accident	6 (30)	6 (11.8)	
Fall from height >1 m	8 (40)	22 (43.1)	
Crush, farm, industrial accident	0 (0)	2 (3.9)	
Unknown	1 (5)	0 (0)	
AO/OTA classification, n (%)			0.047[1]
Type A	5 (25)	3 (5.9)	
Type B	11 (55)	28 (54.9)	
Type C	4 (20)	20 (39.2)	
Young and Burgess classification, n (%)			0.385[1]
Lateral compression	11 (55)	23 (45.1)	
Anteroposterior compression	2 (10)	15 (29.4)	
Vertical shear	0 (0)	1 (2)	
Combined mechanism	2 (10)	10 (19.6)	
Not classifiable	5 (25)	2 (3.9)	
ISS, mean (±SD, range)	45.5 (±14.6, 17–66)	31.3 (±12.3, 9–66)	0.001
ISS categorized, n (%)			0.021[1]
≤15	0 (0)	2 (3.9)	
16≤ ISS ≤24	1 (5)	16 (31.4)	
≥25	19 (95)	33 (64.7)	
Patients needing PRBC within first 24 h, n (%)	16 (80)	32 (62.7)	0.265
PRBC units received within first 24 h	8.7 (±10.4, 6, 2.5–8)	3.8 (±7.4, 2, 0–4.5)	0.072
Patients needing ICU, n (%)	13 (65)	41 (80.4)	0.219[1]
ICU length of stay in days	6.9 (±11.8, 1, 0–7)	12.9 (±14.6, 8, 2.5–18.5)	0.079
Total hospitalization duration in days	8.1 (±12.6, 1, 1–9)	52.4 (±41, 35, 21.5–77.5)	<0.001
Patients presenting complications, n (%)	9 (45)	22 (43.1)	0.999

Continuous variables are expressed as mean (±SD, median, IQ1–3), unless notified otherwise. *P*-values were obtained using Welch *t*-test and Chi squared, or [1]Fischer's exact test.
PRI classifications were simplified to the main types: AO/OTA type A, B and C, and Young and Burgess type lateral compression, anteroposterior compression, vertical shear and combined mechanism.
ICU: intensive care unit. *IQ1–3:* interquartile 1–3. *ISS:* injury severity score. *PRBC:* packed red blood cells. *SD:* standard deviation.

could carry the risk of a small study effect [37,38]. As a result, the data must be confirmed in studies with a larger population.

Urgent pelvic stabilization has been combined with other treatment strategies in management protocols used in the USA and Europe. The Denver protocol has shown that replacing angioembolization and temporary pelvic fixation by pelvic packing and external fixation in 2004 improved in-hospital mortality from 26% to 21% in hemodynamically unstable blunt PRI patients, with percentage of deaths attributed to hemorrhage decreasing from 71% to 11% despite an increase of the mean ISS from 32 to 48 [5,13,14]. In Europe, the Hannover protocol showed a drop of mortality from 46% to 25% with the introduction of pelvic packing by persisting hemodynamic instability 15 min after urgent pelvic C-clamp application [7]. The Grenoble protocol used a pelvic C-clamp followed by angioembolization and occasionally laparotomy in the case of persisting hemodynamic instability [41]: mortality was 9% in patients stabilized by pelvic C-clamp alone, and 42% in those needing angioembolization. In response to the variety of protocols available in the literature, the World Society of Emergency Surgery (WSES) published a guideline as the first attempt to provide a standard of care for high-energy blunt PRI patients, classifying them into minor, moderate and severe PRI, according to both mechanical and hemodynamical stability criteria [1]. In the case of mechanical instability, the first recommended management step is temporary pelvic stabilization, followed by pelvic packing and eventually angioembolization for hemodynamically unstable patients. Angioembolization is indicated in both hemodynamically stable and unstable patients if there is a blush sign on a CT scan. Furthermore, REBOA is considered for *in extremis* hemodynamic stabilization. To date, there is no available study to evaluate the performance of the WSES guideline for final validation. Additionally, comparative studies assessing different protocols in equivalent class-of-risk patients (following the WSES classification, for instance) are lacking. Such studies would be of great interest for determining the treatment with the best mortality and morbidity outcomes, and for standardizing the management of high-energy blunt PRI. As pelvic packing is not used in our institution, we are not able to evaluate if the outcome of the four patients with persisting hemodynamic instability after urgent pelvic mechanical stabilization (50% mortality) would have been different if pelvic packing was used instead of angioembolization.

In the present study, hemodynamically unstable patients that did not survive had higher ISS and higher requirements for PRBC transfusions, compared to hemodynamically stable patients and unstable patients that survived. These findings are in line with previous publications pointing out associated extra-pelvic and vascular injuries rather than bony fracture pattern as determinant of death in this population [35,42-44].

Finally, hemodynamically unstable patients had higher PRBC requirements and a longer ICU stay and total hospitalization compared to stable ones, similar to previous publications [4,39,40,44]. Of note, hemodynamically unstable patients required a mean number of 5.1 PRBC which is consistent with the first step of our institutional massive hemorrhage protocol (5 PRBC, 5 fresh-frozen plasma units and 5 platelet concentrates) and might represent an early control of pelvic ring injury associated hemorrhage following the use of the protocol described in this study.

Our study presents the following limitations: the small sample size, especially for the hemodynamically unstable group, might be associated with the risk of a small-study effect and therefore justifies the importance of confirming our results in a larger population. The design of the study is retrospective, despite the use of data prospectively collected into the SIPR, and carries the risk of recall bias. The impact of both institutional massive transfusion and rewarming protocols on patients' lethal triad of trauma (hypothermia, metabolic acidosis and coagulopathy) was not evaluated [45,46]. Since this study aimed to analyze mortality and survival rates related to the institutional PRI management protocol, associated extra-pelvic injuries were only summarized by using the ISS and AIS, but were not specifically analyzed as possible predictors of mortality; a different study design would have been necessary for this purpose. Finally, the impact of associated surgical procedures (laparotomy, thoracotomy) was not evaluated.

Conclusions

The institutional high-energy blunt PRI management protocol described in this study takes advantage of urgent surgical stabilization of the pelvis when mechanical instability is present, followed by timely angioembolization if persisting hemodynamic instability. Its outcome is encouraging: the mortality rate is comparable to centers using a similar protocol, and lower than protocols using non-surgical pelvic stabilization and alternative techniques of hemorrhage control (REBOA, pelvic packing). Further studies are needed to confirm these results in a larger population, as well as comparative studies to evaluate the performance of different management protocols in equivalent class-of-risk patients.

Declaration of Competing Interest

All the authors confirm that they have no conflicts of interest regarding this study and report. There was no external source of funding or financial support for this study.

Acknowledgments

The authors would like to thank Pr Angèle Gayet-Ageron, MD, PhD, and Mr Cyril Jaksic, BD, PhD, who carried out the statistical analysis (Clinical Research Center & Division of Clinical Epidemiology, Department of health and community medicine, University of Geneva & University Hospitals of Geneva, 4 Rue Gabrielle-Perret-Gentil, CH-1211 Geneva 14, Switzerland) as well as Dr Haqeeqat Singh Gurm, MD, for writing assistance (Ortho-Geriatrics, Conquest Hospital, East Sussex Healthcare NHS, St-Leonards-on-Sea, UK).

References

[1] Coccolini F, Stahel PF, Montori G, Biffl W, Horer TM, Catena F, et al. Pelvic trauma: WSES classification and guidelines. World J Emerg Surg 2017;12:5.
[2] Biffl WL, Smith WR, Moore EE, Gonzalez RJ, Morgan SJ, Hennessey T, et al. Evolution of a multidisciplinary clinical pathway for the management of unstable patients with pelvic fractures. Ann Surg 2001;233(6):843–50.
[3] Burlew CC, Moore EE, Stahel PF, Geddes AE, Wagenaar AE, Pieracci FM, et al. Preperitoneal pelvic packing reduces mortality in patients with life-threatening hemorrhage due to unstable pelvic fractures. J Trauma Acute Care Surg 2017;82(2):233–42.
[4] Costantini TW, Coimbra R, Holcomb JB, Podbielski JM, Catalano R, Blackburn A, et al. Current management of hemorrhage from severe pelvic fractures: results of an American Association for the Surgery of Trauma multi-institutional trial. J Trauma Acute Care Surg 2016;80(5):717–23.
[5] Moreno C, Moore EE, Rosenberger A, Cleveland HC. Hemorrhage associated with major pelvic fracture: a multispecialty challenge. J Trauma 1986;26(11):987–94.
[6] Margolies MN, Ring EJ, Waltman AC, Kerr WS Jr, Baum S. Arteriography in the management of hemorrhage from pelvic fractures. N Engl J Med 1972;287(7):317–21.
[7] Pohlemann T, Gänsslen A, Bosch U, Tscherne H. The technique of packing for control of hemorrhage in complex pelvic fractures. Techniq Orthopaed 1994;9(4):267–70.
[8] Smith WR, Moore EE, Osborn P, Agudelo JF, Morgan SJ, Parekh AA, et al. Retroperitoneal packing as a resuscitation technique for hemodynamically unstable patients with pelvic fractures: report of two representative cases and a description of technique. J Trauma 2005;59(6):1510–14.
[9] Brenner ML, Moore LJ, DuBose JJ, Tyson GH, McNutt MK, Albarado RP, et al. A clinical series of resuscitative endovascular balloon occlusion of the aorta for hemorrhage control and resuscitation. J Trauma Acute Care Surg 2013;75(3):506–11.
[10] Gansslen A, Hildebrand F, Pohlemann T. Management of hemodynamic unstable patients "in extremis" with pelvic ring fractures. Acta Chir Orthop Traumatol Cech 2012;79(3):193–202.
[11] Abboud AE, Boudabbous S, Andereggen E, de Foy M, Ansorge A, Gamulin A. Incidence rate and topography of intra-pelvic arterial lesions associated with high-energy blunt pelvic ring injuries: a retrospective cohort study. BMC Emerg Med 2021;21(1):75.
[12] Charbit J, Ramin S, Hermida M, Cavaille P, Murez T, Taourel P, et al. A simple CT score to quantify pelvic and retroperitoneal hematoma associated with pelvic fractures predicts transfusion needs, pelvic hemostatic procedures, and outcome. Emerg Radiol 2020;27(2):173–84.
[13] Parry JA, Smith WR, Moore EE, Burlew CCC, Mauffrey C. The past, present, and future management of hemodynamic instability in patients with unstable pelvic ring injuries. Injury 2020.
[14] Burlew CC, Moore EE, Smith WR, Johnson JL, Biffl WL, Barnett CC, et al. Preperitoneal pelvic packing/external fixation with secondary angioembolization: optimal care for life-threatening hemorrhage from unstable pelvic fractures. J Am Coll Surg 2011;212(4):628–35 discussion 35-7.
[15] Salcedo ES, Brown IE, Corwin MT, Galante JM. Pelvic angioembolization in trauma - Indications and outcomes. Int J Surg 2016;33(Pt B):231–6.
[16] Tosounidis TI, Giannoudis PV. Pelvic fractures presenting with haemodynamic instability: treatment options and outcomes. Surgeon 2013;11(6):344–51.
[17] Abrassart S, Stern R, Peter R. Unstable pelvic ring injury with hemodynamic instability: what seems the best procedure choice and sequence in the initial management? Orthop Traumatol Surg Res 2013;99(2):175–82.
[18] Sadri H, Nguyen-Tang T, Stern R, Hoffmeyer P, Peter R. Control of severe hemorrhage using C-clamp and arterial embolization in hemodynamically unstable patients with pelvic ring disruption. Arch Orthop Trauma Surg 2005;125(7):443–7.
[19] Organe de décision de la Convention intercantonale relative à la médecine hautement spécialisée (Organe de décision MHS). Décision concernant la planification de la médecine hautement spécialisée (MHS) dans le domaine de la prise en charge des blessés graves. May 20, 2011. Available from: https://www.admin.ch/opc/fr/federal-gazette/2011/4350.pdf.
[20] American College of Surgeons Committee on Trauma. Resources for optimal care of the injured patient. Chicago, IL: American College of Surgeons; 2006.
[21] Vermeulen B, Peter R, Hoffmeyer P, Unger PF. Prehospital stabilization of pelvic dislocations: a new strap belt to provide temporary hemodynamic stabilization. Swiss Surg 1999;5(2):43–6.
[22] American College of Surgeons Committee on Trauma Advanced trauma life support ATLS. 9th ed. Chicago, IL: American College of Surgeons; 2012.
[23] Kim WY, Hearn TC, Seleem O, Mahalingam E, Stephen D, Tile M. Effect of pin location on stability of pelvic external fixation. Clin Orthop Relat Res 1999(361):237–44.
[24] Noordeen MH, Taylor BA, Briggs TW, Lavy CB. Pin placement in pelvic external fixation. Injury 1993;24(9):581–4.
[25] Poka A, Libby EP. Indications and techniques for external fixation of the pelvis. Clin Orthop Relat Res 1996(329):54–9.
[26] Ganz R, Krushell RJ, Jakob RP, Kuffer J. The antishock pelvic clamp. Clin Orthop Relat Res 1991(267):71–8.
[27] Meinberg EG, Agel J, Roberts CS, Karam MD, Kellam JF. Fracture and dislocation classification compendium-2018. J Orthop Trauma 2018;32(1):S1–S170 Suppl.
[28] Manson T, O'Toole RV, Whitney A, Duggan B, Sciadini M, Nascone J. Young-Burgess classification of pelvic ring fractures: does it predict mortality, transfusion requirements, and non-orthopaedic injuries? J Orthop Trauma 2010;24(10):603–9.
[29] Baker SP, O'Neill B, Haddon W Jr, Long WB. The injury severity score: a method for describing patients with multiple injuries and evaluating emergency care. J Trauma 1974;14(3):187–96.
[30] Copes WS, Champion HR, Sacco WJ, Lawnick MM, Keast SL, Bain LW. The injury severity score revisited. J Trauma 1988;28(1):69–77.
[31] Young JW, Burgess AR, Brumback RJ, Poka A. Pelvic fractures: value of plain radiography in early assessment and management. Radiology 1986;160(2):445–51.
[32] Schmal H, Froberg L, SL M, Sudkamp NP, Pohlemann T, Aghayev E, et al. Evaluation of strategies for the treatment of type B and C pelvic fractures: results from the German Pelvic Injury Register. Bone Joint J 2018;100-B(7):973–83.
[33] Boyd CR, Tolson MA, Copes WS. Evaluating trauma care: the TRISS method. Trauma Score and the Injury Severity Score. J Trauma 1987;27(4):370–8.
[34] Butcher N, Balogh ZJ. The definition of polytrauma: the need for international consensus. Injury 2009;40(4):S12–22 Suppl.
[35] Wang H, Robinson RD, Moore B, Kirk AJ, Phillips JL, Umejiego J, et al. Predictors of early versus late mortality in pelvic trauma patients. Scand J Trauma Resusc Emerg Med 2016;24:27.
[36] Valisena S., Abboud A.E., Andereggen E., Ansorge A., Gamulin A. High-energy blunt pelvic ring injury: dataset of patients and injury characteristics from a severely injured patients' registry. Data in brief. In Press.2022
[37] Jeske HC, Larndorfer R, Krappinger D, Attal R, Klingensmith M, Lottersberger C, et al. Management of hemorrhage in severe pelvic injuries. J Trauma 2010;68(2):415–20.
[38] Metsemakers WJ, Vanderschot P, Jennes E, Nijs S, Heye S, Maleux G. Transcatheter embolotherapy after external surgical stabilization is a valu-

able treatment algorithm for patients with persistent haemorrhage from unstable pelvic fractures: outcomes of a single centre experience. Injury 2013;44(7):964–8.
[39] Costantini TW, Coimbra R, Holcomb JB, Podbielski JM, Catalano RD, Blackburn A, et al. Pelvic fracture pattern predicts the need for hemorrhage control intervention-Results of an AAST multi-institutional study. J Trauma Acute Care Surg 2017;82(6):1030–8.
[40] Duchesne J, Costantini TW, Khan M, Taub E, Rhee P, Morse B, et al. The effect of hemorrhage control adjuncts on outcome in severe pelvic fracture: a multi-institutional study. J Trauma Acute Care Surg 2019;87(1):117–124.
[41] Ruatti S, Guillot S, Brun J, Thony F, Bouzat P, Payen JF, et al. Which pelvic ring fractures are potentially lethal? Injury 2015;46(6):1059–63.
[42] Lunsjo K, Tadros A, Hauggaard A, Blomgren R, Kopke J, Abu-Zidan FM. Associated injuries and not fracture instability predict mortality in pelvic fractures: a prospective study of 100 patients. J Trauma 2007;62(3):687–91.
[43] Smith W, Williams A, Agudelo J, Shannon M, Morgan S, Stahel P, et al. Early predictors of mortality in hemodynamically unstable pelvis fractures. J Orthop Trauma 2007;21(1):31–7.
[44] Wu YT, Cheng CT, Tee YS, Fu CY, Liao CH, Hsieh CH. Pelvic injury prognosis is more closely related to vascular injury severity than anatomical fracture complexity: the WSES classification for pelvic trauma makes sense. World J Emerg Surg 2020;15(1):48.
[45] Eddy VA, Morris JA Jr. Cullinane DC. Hypothermia, coagulopathy, and acidosis. Surg Clin North Am 2000;80(3):845–54.
[46] Mitra B, Tullio F, Cameron PA, Fitzgerald M. Trauma patients with the 'triad of death'. Emerg Med J 2012;29(8):622–5.