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SYMPOSIUM: DISRUPTIONS OF THE PELVIC RING: AN UPDATE

What are Predictors of Mortality in Patients with Pelvic Fractures?

Joerg H. Holstein MD, Ulf Culemann MD,
Tim Pohlemann MD, Working Group Mortality in Pelvic Fracture Patients

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Abstract

Background Our knowledge of factors influencing mortality of patients with pelvic ring injuries and the impact of associated injuries is currently based on limited information.

Questions/purposes We identified the (1) causes and time of death, (2) demography, and (3) pattern and severity of injuries in patients with pelvic ring fractures who did not survive.

Methods We prospectively collected data on 5340 patients listed in the German Pelvic Trauma Registry between April 30, 2004 and July 29, 2011; 3034 of 5340 (57%) patients were female. Demographic data and parameters indicating the type and severity of injury were recorded for patients who died in hospital (nonsurvivors) and compared with data of patients who survived (survivors). The median followup was 13 days (range, 0–1117 days).

Results A total of 238 (4%) patients died a median of 2 days after trauma. The main cause of death was massive bleeding (34%), predominantly from the pelvic region (62% of all patients who died because of massive bleeding). Fifty-six percent of nonsurvivors and 43% of survivors were male. Nonsurvivors were characterized by a higher incidence of complex pelvic injuries (32% versus 8%), less isolated pelvic ring fractures (13% versus 49%), lower initial blood hemoglobin concentration (6.7 ± 2.9 versus 9.8 ± 3.0 g/dL) and systolic arterial blood pressure (77 ± 27 versus 106 ± 24 mmHg), and higher injury severity score (ISS) (35 ± 16 versus 15 ± 12).

Conclusion Patients with pelvic fractures who did not survive were characterized by male gender, severe multiple trauma, and major hemorrhage.

Level of Evidence Level III, prognostic study. See Guidelines for Authors for a complete description of levels of evidence.

The members of the Working Group Mortality in Pelvic Fracture Patients are:
Georgios Tosounidis, MD
Markus Burkhardt, MD
Department of Trauma, Hand, and Reconstructive Surgery, University of Saarland, Homburg, Germany
Emin Aghayev, MD
Institute for Evaluative Research in Medicine, University of Bern, Bern, Switzerland
Jörg Böhme, MD
University Hospital Leipzig, Leipzig, Germany
Hagen Schmal, MD
University Hospital Freiburg, Freiburg, Germany

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Each author certifies that his or her institution approved the human protocol for this investigation and that all investigations were conducted in conformity with ethical principles of research. The institutional review boards of all investigational sites approved the study, and waived written informed consent because of the use of routine administrative hospital data.

Data were collected at the collaborating institutions as reported in the Acknowledgement section and analyzed at the Department of Trauma, Hand, and Reconstructive Surgery, University of Saarland, and the Institute for Evaluative Research in Medicine at the University of Bern.

J. H. Holstein (✉), U. Culemann, T. Pohlemann
Department of Trauma, Hand, and Reconstructive Surgery, University of Saarland, Kirrberger Strasse 1, 66421 Homburg, Germany
e-mail: joerg.holstein@uks.eu

Introduction

Fractures of the pelvic ring are relatively uncommon, with a reported incidence of 2% to 8% of all fractures [5, 10, 34]. In multiple-trauma patients, however, the frequency of pelvic ring fractures rises dramatically, with an incidence of around 25% [19, 34, 37]. In young patients, pelvic ring fractures have mostly been caused by high-energy trauma, such as traffic accidents or falls from altitude, implying an increased risk for associated injuries of other body regions [16, 34]. The pelvic ring, with its tight sacra-iliac, sacra-tuberous, and sacra-spinous ligaments provides a stable compartment for the neurovascular and hollow, visceral structures of the pelvis [16]. Accordingly, disruption of the pelvic ring has reportedly placed patients at a high risk for severe hemorrhage and other life threatening complications [16, 44]. In contrast to young patients, pelvic injuries in the elderly have often been caused by low-energy traumas [30, 43]. During the past decades, the number of pelvic fractures in the elderly has increased consistently [11, 26, 42, 43].

One of the central challenges for the clinician managing a patient with pelvic ring fracture has been determining the most immediate threat to life and controlling this threat. Treatment approaches have varied depending on whether the main threat arises from pelvic injury, injuries of other body regions, or both simultaneously [16]. To identify prognostic factors and evaluate the impact of associated injuries on mortality of patients with pelvic ring fractures, we studied the causes and time points of death, demographic data, and parameters indicating the type and severity of injury of 238 patients who died in hospital with pelvic ring fractures.

We therefore addressed the following questions: (1) what were the most frequent causes and time points of death in patients with pelvic ring fractures who do not survive, and what were the differences in (2) demographic characteristics and (3) severity and pattern of injuries between patients with pelvic ring fractures who survived (survivors) and those who did not survive (nonsurvivors)?

Patients and Methods

The German Pelvic Trauma Registry collected data of individuals with pelvic fractures during the time periods from 1991 to 1993, 1998 to 2000, and 2004 to 2011. To ensure use of contemporary approaches, we used data from this registry recorded between April 30, 2004 and July 29, 2011 on 5340 patients who had fractures and disruptions of the pelvic ring at 31 medical centers. Each institution participating on the German Pelvic Trauma Registry committed to include every inpatient with a pelvic fracture in the registry

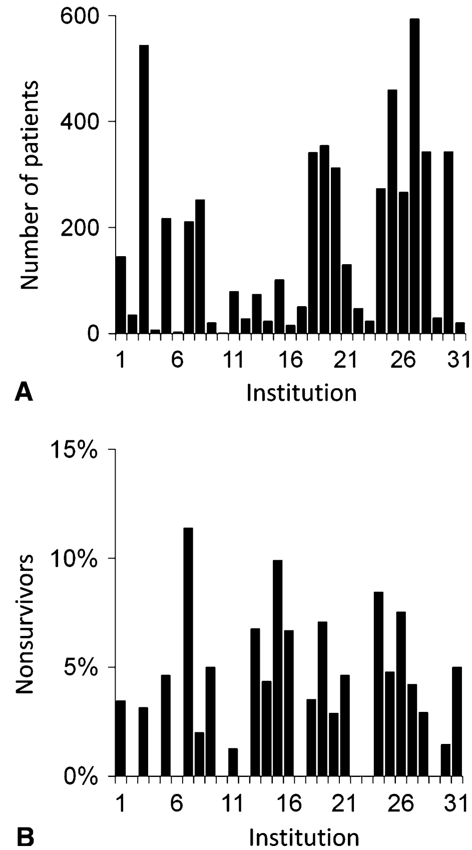

Fig. 1A–B We used data from the German Pelvic Trauma Registry including 5340 patients from 31 medical centers (each institution is represented by a black column). (**A**) This graph shows the number of patients included by each center. (**B**) This graph shows the fraction of nonsurvivors in each center. There were no deaths with pelvic ring fractures in 9 institutions.

(Fig. 1A). The majority of the participating institutions (listed in the Acknowledgments) fulfilled the requirements of a Level I trauma center according to the classification of the American College of Surgery [3] and the German Trauma Society [3, 39]. Data were collected and processed using a standardized data sheet. For this purpose, a secured Internet interface hosted by a professional service provider (MEMDoc®, Institute for Evaluative Research in Medicine, Bern, Switzerland) was used. The registration was performed as soon as possible after the admission of the patient and updated consistently during the followup by a trauma surgeon or study nurse. We excluded patients with isolated acetabular fractures because we considered this injury to have no substantial impact on hospital mortality [33]. The age range of the study population was 2 to 105 years, with a mean age of 58 ± 24 years. Fifty-seven percent of all patients were female. Two-hundred thirty-eight (4%) of these patients died in hospital (nonsurvivors), while 5102 (96%) patients survived (survivors). We recorded the fraction of nonsurvivors for each institution (Fig. 1B). We also recorded the data for nonsurvivors and, if applicable, compared them with data of survivors. We defined the followup time as the time between admission and discharge from hospital. The median followup was 13 days (range, 0–1117 days). No patients were lost to followup, and we did not recall any specifically for this study; we obtained all data from medical records and radiographs. The institutional review boards of all investigational sites approved the study, and waived written informed consent because of the use of routine administrative hospital data. This cohort study was conducted according to the recommendations and guidelines of the STROBE initiative [45].

Post hoc Mann-Whitney U test and post hoc chi-square test revealed a power of greater than 0.99, given a sample size of 5340, with an alpha error of 0.05 and differences between the means of the two study groups of 24% for incidence of complex pelvic injuries, 36% for incidence of isolated pelvic ring fractures, 3.1 g/dL for initial blood hemoglobin concentration, 29 mmHg for initial systolic arterial blood pressure, 20 points for injury severity score (ISS), 21 points for polytrauma score (PTS), and eight units of packed red blood cells transfused within the first 6 hours after trauma.

The most frequent reasons for injury in nonsurvivors were traffic accidents, including car, motorcycle, bicycle, and pedestrian accidents, and falls from high altitude, including suicide jumps. The majority of patients (76%) were admitted to an institution contributing to the German Pelvic Trauma Registry on the day of injury. The remaining patients were referred from other hospitals at a median of 6 days.

All patients of the study population underwent clinical and radiographic examination on initial admission to the institution contributing to the German Pelvic Trauma Registry. Images included pelvic radiographs and, depending on the fracture type and medical condition of the patient, additional CT scans. Examination and initial treatment of multiple trauma patients was performed according to Advanced Trauma Life Support (ATLS) guidelines [29]. Outcome measures included demographic parameters and parameters characterizing pattern and severity of injuries. Additionally, we evaluated causes and time points of death for nonsurvivors. Pelvic ring fractures were classified using Tile's classification system adopted by the Orthopaedic Trauma Association (OTA) [41]. Stable pelvic ring fractures were classified as Type A, fractures with only rotational instability as Type B, and fractures with both rotational and translational instability as Type C injuries. We defined Type B and C injuries with major visceral, neurovascular, or soft tissue injuries as complex pelvic injuries [7, 12]. We assessed patients on whether they had sustained isolated pelvic ring fractures or pelvic ring fractures with additional injuries to other body regions. We used the ISS and PTS to estimate the severity of injuries [4, 40]. Hemodynamic stability of the patients was indicated by initial blood hemoglobin concentration and systolic arterial blood pressure, as well as transfusion requirement of packed red blood cells.

We presented data as percent, median with interquartile limits, or mean ± SD. After checking normality of distributions and equal variance, we determined differences in age, sex, fracture type, and incidence of complex, and isolated pelvic ring fractures between survivors and nonsurvivors by using the chi-square test. Differences in initial blood hemoglobin concentration and systolic arterial blood pressure, ISS and PTS, as well as the number of units of packed red blood cells transfused within the first 24 hours between survivors and nonsurvivors were analyzed using the Mann-Whitney U test. All statistical analyses were performed using the SPSS® software package, Version 17.0 for Windows (SPSS® Inc., Chicago, IL, USA).

Results

The most often cause of death was massive bleeding (Fig. 2A). Regarding the body region, head injuries were the predominant reason for death in patients who died with pelvic ring fractures (Fig. 2A). In 64 of 238 (27%) cases, injuries of the pelvis led to death (Fig. 2A). The pelvis was the primary origin of bleeding (Fig. 2B). In 22 of 80 (28%) cases, the bleeding was limited to the pelvis. More than 50% of nonsurvivors died within the first 2 days after trauma (93 of 238 [39%] patients during the first 24 hours, 126 of 238 [53%] patients during the first 48 hours) (Fig. 3). Twenty-four of 238 (10%) patients died more than 1 month after trauma (Fig. 3). Of the patients who did not survive, 16 (7%) died due to an injury of the pelvic ring alone, 15 (94%) of whom died due to massive bleeding. Nine (56%) of these patients did not survive the first 24 hour after trauma, and 12 (75%) died within the first 2 days after trauma. None of these patients survived the first month after trauma.

The age of patients who died with a pelvic ring fracture was comparable ($p = 0.76$) to that of survivors (57 ± 25 years versus 58 ± 24 years) (Fig. 4). In both groups, around 40% of patients were older than 70 years of age (Fig. 4). The fraction of male patients was higher ($p < 0.001$) in the group of nonsurvivors (134 of 238 [56%] patients) than in the group of survivors (2172 of 5102 [43%] patients).

Nonsurvivors had higher incidence of Type C fractures (Fig. 5A). The mortality rate was higher in patients with Type C fractures than in patients with Type A and B fractures, as well as in patients with nonisolated pelvic fractures than in patients with isolated pelvic fractures (Fig. 5B). The fraction of complex pelvic injuries was greater in nonsurvivors than in survivors (Fig. 6A). Nonsurvivors had a lesser incidence of isolated pelvic ring fractures compared

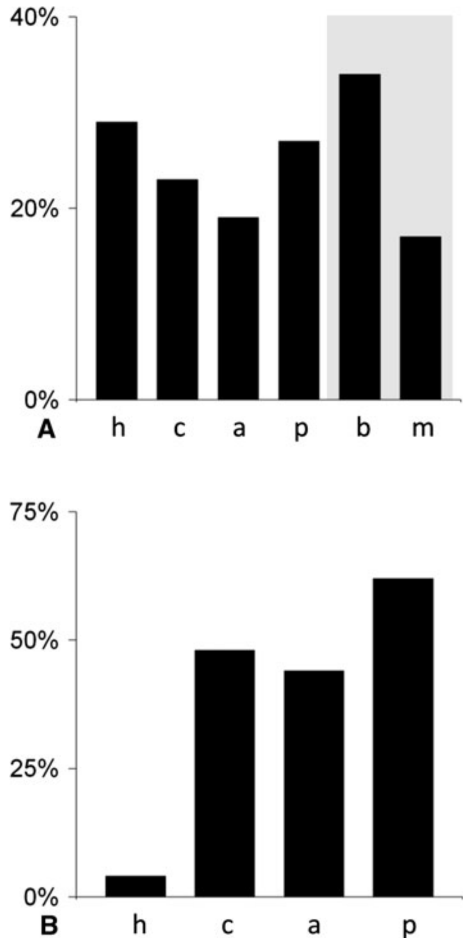

Fig. 2A–B (**A**) This graph shows the causes of death in patients with pelvic fracture included injuries of the head (h), chest (c), abdomen (a), and pelvis (p). Most common general reasons not related to a specific body region were bleeding (b) and multiple organ failure (m) (highlighted in gray). Multiple reasons of death were possible. (**B**) This graph shows the origin of lethal bleeding included the head (h), chest (c), abdomen (a), and pelvis (p). Multiple origins of lethal bleeding were possible.

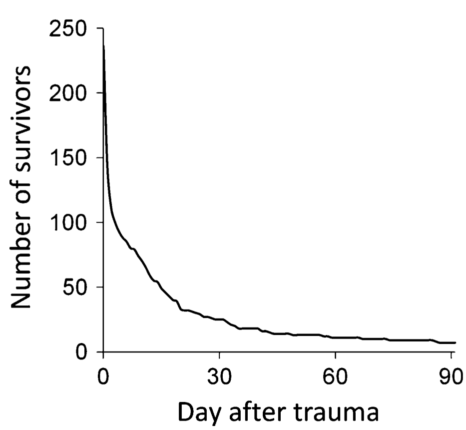

Fig. 3 The graph shows the survival curves of patients who died with pelvic ring fractures. More than 50% of patients who did not survive died within the first 2 days after trauma, while 3% of patients died later than 3 months after trauma.

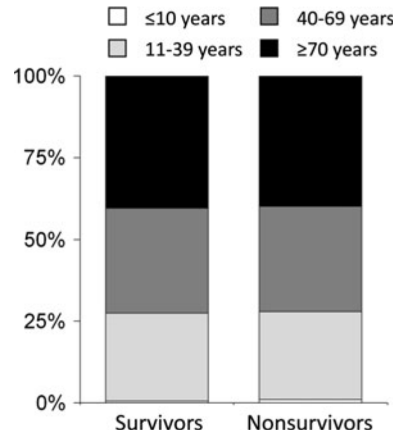

Fig. 4 This graph shows the age distribution of inpatients who survived (survivors) versus inpatients who died (nonsurvivors) after pelvic ring fracture. The age distribution of nonsurvivors was comparable to that of survivors

to survivors (Fig. 6B). The initial blood hemoglobin concentration and systolic arterial blood pressure were lower in patients who died compared to those who survived (Table 1). Both ISS and PTS were higher in nonsurvivors than in survivors (Table 1). In the group of nonsurvivors, more units of packed red blood cells were transfused within the first 12 hours after trauma compared to survivors (Table 2). In contrast, we observed no differences between survivors and nonsurvivors regarding the need of red blood cell transfusion later than 12 hours after trauma (Table 2).

Discussion

Pelvic ring fractures are mostly caused by high-energy impact, and, therefore, are often related to multiple traumas [16, 18, 19, 34, 37]. For clinicians managing a patient with pelvic ring fracture, it is of utmost importance to recognize life threatening injuries of the pelvis itself or other body regions. Accordingly, it is important to identify patients who are critical and need immediate measures to survive. Therefore, we raised the following questions: (1) what were the most frequent causes and time point of death in patients with pelvic ring fractures who do not survive, and what were the differences in (2) demographic characteristics and (3) severity and pattern of injuries between patients with pelvic ring fractures who survived and those who did not survive?

We noted several limitations to our study. First, the study population mainly included patients of Level I trauma centers. This fact might have limited the external validity of the study because the causes and time points of death, as well as severity and pattern of injuries, might have been different in patients who died in lower level trauma centers. To investigate the external validity, it would be necessary to

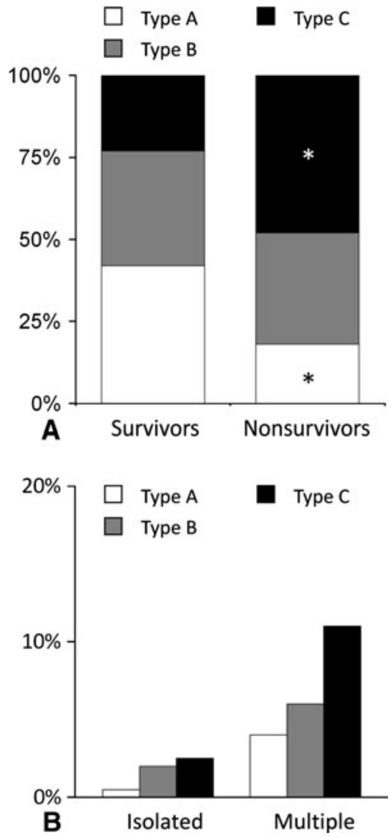

Fig. 5A–B (**A**) This graph shows Tile's classification adopted by the Orthopaedic Trauma Association (OTA) [41] of pelvic ring fractures of patients who survived versus those who did not. Stable pelvic ring fractures were classified as Type A, fractures with only rotational instability as Type B, and fractures with both rotational and translational instability as Type C injuries. The fraction of Type C fractures was greater (*$p < 0.001$) in nonsurvivors than in survivors, while the fraction of Type A fractures was less (*$p < 0.001$) in nonsurvivors than in survivors. (**B**) This graph shows the mortality rate in patients with isolated pelvic fractures versus nonisolated pelvic fractures (multiple) stratified by the fracture type. The mortality rate was higher in patients with Type C fractures than in patients with Type B and A fractures, as well as in patients with nonisolated pelvic fractures than in patients with isolated pelvic fractures.

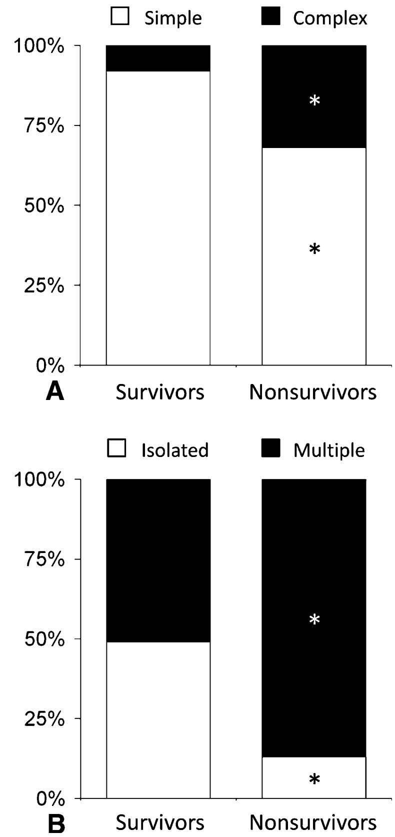

Fig. 6A–B These graphs show the fraction of (**A**) complex pelvic injuries and (**B**) isolated pelvic fractures in patients who survived (survivors) versus patients who died (nonsurvivors) after pelvic ring fracture. The fraction of complex and nonisolated pelvic fractures (multiple) was greater (*$p < 0.001$) in nonsurvivors than in survivors, while the fraction of simple and isolated pelvic fractures was lesser (*$p < 0.001$) in nonsurvivors than in survivors.

acquire data from institutions other than Level I trauma centers. Second, there was a wide age range in the study population. Thus, factors associated with death may have differed between young and old individuals, and data of the total study population may not have referred to individuals of each age group. We did not stratify our data by age because of inadequate power. Third, some patients may have died after referral to another facility. However, this number was probably very small, because all institutions contributing to the German Pelvic Trauma Registry were specialized on the treatment of multiple trauma and pelvic fractures, and patients of these hospitals were generally not referred to other institutions. Fourth, we did not account for patients who died before admission to hospital or after discharge from hospital; however, it is challenging to

Table 1. Indicators of the severity of injury

Group	Hb (g/dL)	ABP (mmHg)	ISS	PTS
Survivors	10 (8; 12)	110 (98; 120)	9 (4; 21)	24 (14; 30)
Nonsurvivors	7 (4; 9)	80 (60; 90)	34 (22; 48)	43 (30; 59)
p value	$p < 0.001$	$p < 0.001$	$p < 0.001$	$p < 0.001$

Hb = hemoglobin concentration; ABP = systolic arterial blood pressure; ISS = injury severity score; PTS = polytrauma score. Data are given as medians with interquartile limits.

analyze causes of death in patients who died before admission to hospital, and to prove a relation between death and trauma history in patients who died after discharge.

We identified the most frequent causes and time points of death in patients with pelvic ring fractures who did not survive. The mortality rate of our study population was 4%, lower than mortality rates reported by most previous studies [1, 5, 6, 14, 15, 20, 21, 25, 27, 35, 36, 38]. This reduction of mortality might be explained by constant

Table 2. Units of packed red blood cells transfused within 24 hours after trauma.

Group	Units during the first to sixth hour	Units during the seventh to twelfth hour	Units during the thirteenth to twenty-fourth hour
Survivors	2 (0; 6)	0 (0; 4)	0 (0; 2)
Nonsurvivors	10 (6; 10)	0 (0; 8)	0 (0; 3)
p value	$p < 0.001$	$p = 0.02$	$p = 0.55$

Data are given as medians with interquartile limits.

progresses in the early treatment of pelvic ring injuries, including immediate mechanical stabilization of the pelvic ring and improved bleeding control techniques, but also by progresses in intensive care medicine and emergency management of multiple traumas [17, 46]. We found most patients died from head injuries, followed by pelvic injuries. The predominant cause of death was major hemorrhage, and the primary source of lethal bleeding was the pelvis. However, in a substantial number of cases, mortality was not caused by the pelvic injury alone, but by a combination of multiple injuries to different body regions, including the pelvis. While brain injuries were consistently reported as a main reason for mortality in pelvic fracture patients, data from the literature on the incidence of lethal pelvic bleeding were conflicting [21, 23, 25, 27, 35, 36]. This heterogeneity of data might have been due to the fact that isolated pelvic fractures were rarely lethal injuries, but a combination of pelvic and abdominal or thoracic bleeding often took a fatal course. Also, we found mortality was caused by a pelvic fracture alone in only 7% of cases, while pelvic fractures in combination with other injuries were related to mortality in 27% of cases.

The majority of patients who did not survive died within the first couple days after trauma. Typical reasons for early death after trauma have included severe head injuries and hemorrhagic shock [27, 31]. Therefore, the high incidence of these lethal injuries in our study explained the initial peek of deaths during the first 48 hour after trauma. In contrast, the second mortality peak of multiple trauma patients reported in the past was not that evident in our study [22, 24, 31]. This might have resulted from an improvement in critical care medicine, leading to a reduced incidence of secondary complications, like multiple organ failure and sepsis. The correlation between massive bleeding and high initial mortality rate was most obvious in individuals who died due to pelvic ring fractures alone. Seventy-five percent of this small group of patients did not survive the first 2 days after trauma, almost exclusively because of major hemorrhage.

We found a higher mortality rate in male patients, but no differences in age distribution between survivors and nonsurvivors. The increased mortality of male patients corresponded with data from the literature that demonstrated a gender dimorphism in the responsiveness to hemorrhage and sepsis [2, 9, 28]. This dimorphism could have been partially explained by the role of sex hormones and the immune system in the patient's response to shock and trauma [2, 9, 28]. The incidence of pelvic ring fractures in the elderly has increased during the past decades [26, 43]. Accordingly, our study population included a high fraction of individuals over 70 years of age. Most authors have reported a higher mortality rate of elderly patients compared to young patients sustaining pelvic fractures [8, 30, 42]. Therefore, we were surprised that both the mean age and age distribution of survivors and nonsurvivors did not differ in this study. This may have been explained by the fact that young patients were more often affected by high-energy traumas than elderly patients, which implied a higher risk of lethal injuries to other body regions. Another explanation may have been an improved treatment regime of elderly patients compared to the past.

Patients who did not survive had a higher incidence of Type C and complex pelvic injuries. This finding agreed with data of previous studies [13, 32–35], and confirmed severe pelvic injuries were associated with an increased mortality. However, we also found the majority of nonsurvivors sustained severe multiple trauma. Accordingly, both ISS and PTS of nonsurvivors were more than two times higher than the scores of survivors. Thus, we confirmed the minority of patients died from isolated pelvic ring fractures, whereas multiple trauma patients with pelvic ring fractures were at higher risk to die mainly from brain injuries and bleeding [21, 25, 27, 33, 35]. The relevance of major hemorrhage as cause of mortality in pelvic fracture patients was highlighted by the low initial blood hemoglobin concentration and arterial blood pressure, as well as the high requirement of blood transfusion during the first hours after trauma in patients who did not survive.

In conclusion, our data suggest male patients and multiple-trauma patients with pelvic ring fractures were at an increased risk to die from massive bleeding and brain injuries. The highest risk of dying exists during the first 2 days after trauma.

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