

## Review

## Pelvic fracture in multiple trauma: Are we still up-to-date with massive fluid resuscitation?



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## ABSTRACT

Until today the mortality of complex pelvic trauma remains unacceptably high. On the one hand this could be attributed to a biological limit of the survivable trauma load, on the other hand side an ongoing inadequate treatment might be conceivable too. For the management of multiple trauma patients with life-threatening pelvic fractures, there is ongoing international debate on the adequate therapeutic strategy, e.g. arterial embolization or pelvic packing, as well as aggressive or restrained volume therapy. Whereas traditional pelvis-specific trauma algorithms still recommend massive fluid resuscitation, there is upcoming evidence that a restrained volume therapy in the preclinical setting may improve trauma outcomes. Less intravenous fluid administration may also reduce haemodilution and concomitant trauma-associated coagulopathy. After linking the data of the TraumaRegister DGU<sup>®</sup> and the German Pelvic Injury Register, for the first time, the initial fluid management for complex pelvic traumas as well as for different Tile/OTA types of pelvic ring fractures could be addressed. Unfortunately, the results could not answer the question of the adequate fluid resuscitation but confirmed the actuality of massive fluid resuscitation in the prehospital and emergency room setting. Low-volume resuscitation seems not yet accepted in practice in managing multiple trauma patients with pelvic fractures at least in Germany. Nevertheless, prevention of exsanguination and of complications like multiple organ dysfunction syndrome still poses a major challenge in the management of complex pelvic ring injuries. Even nowadays, fluid management for trauma, not only for pelvic fractures, remains a controversial area and further research is mandatory.

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**Introduction**

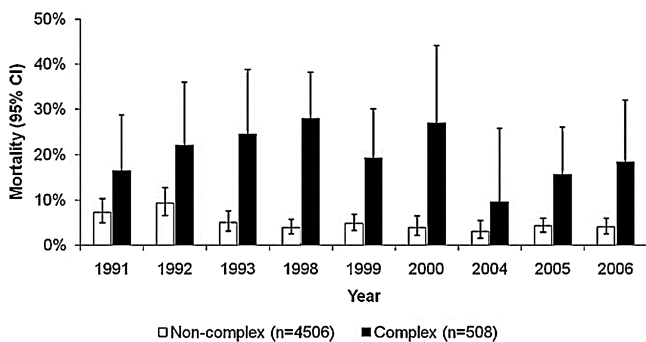
Pelvic fractures are relatively uncommon with a reported incidence of only 2–8% of all fractures, but in multiple trauma patients, the frequency can rise up to more than 25% [1–4]. The risk of haemorrhage makes pelvic fractures the most serious skeletal injury resulting in substantial mortality that ranges from 5% to 50% in the literature and is dependent not only on the type of pelvic ring fracture but also on the severity of associated injuries involving the abdomen, chest, and central nervous system [5–12]. Even if actual studies found out a distinct decrease over the time, until today, the mortality rate of multiple trauma patients with so called “complex pelvic traumas” remains unacceptably high, approximately 18% [11,12] (Fig. 1). Thereby, the definition for “complex pelvic trauma” is the association with pelvic soft tissue injuries, e.g. open fracture including Morel-Lavallée lesion, disruption of pelvic vessels including retroperitoneal haematoma, urogenital injuries, hollow viscous injuries or neurologic deficits directly caused by the pelvic fracture [5]. On the one hand this stagnation of mortality could be attributed to a biological limit of the survivable trauma load, on the other hand side an ongoing inadequate treatment might be conceivable too.

**Pelvic anatomy and sources of bleeding**

The pelvic ring comprises of a three-element bony ring, formed by the ligamentous juncture of the sacrum and both innominate bones. With its tight sacra-iliac, sacra-tuberous, and sacra-spinous ligaments, normally, the pelvic ring provides a stable compartment for the neurovascular and visceral structures of the pelvis. In case of pelvic fractures haemorrhage can be generated from iliac arterial branches, the presacral venous plexus, or the large bulk of cancellous bone, whereby the blood loss typically is retroperitoneal. Unfortunately, it is difficult to know the proportional contributions of venous and arterial bleeding to the overall pelvic haemorrhage. In contrast to the self-limiting fracture bleeding at the extremities, the bleeding of the pelvic fractures follows the “chimney effect”. Because of the disrupted compartments in the retroperitoneal area, there is no self-tamponade and the patient is at high risk to bleed to death [5–7]. Thus, to stop the intrapelvic bleeding represents the most important step in the emergency management of this fracture entity followed by optimizing the patient’s ability to coagulate the bleeding vessels [13].

**Pelvic ring fracture classification**

The two most commonly utilized classifications are those described by Tile [14] and by Young and Burgess [15]. While the

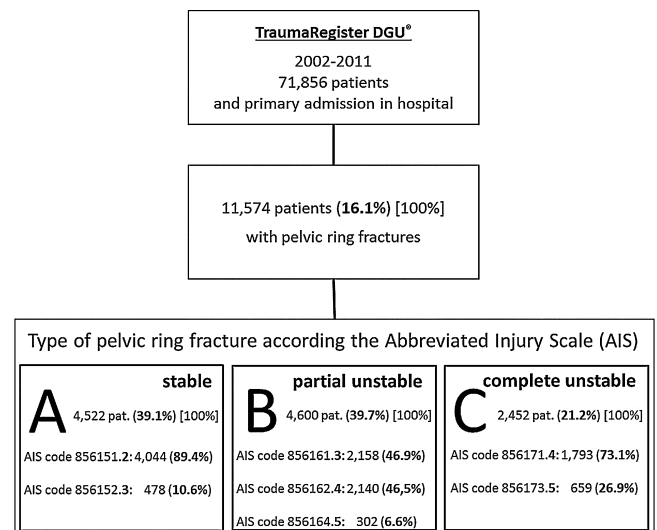


**Fig. 1.** Stratified risk of mortality in patients with non-complex and complex pelvic trauma. Source: Data from the German Pelvic Injury Register. Modified from Pohlemann et al. [11].

classification system by Tile primarily focuses on the stability of the posterior pelvic ring, Young and Burgess, in addition, brought the concept of the underlying trauma mechanism into the focus. In contrast to the Anglo-American world, in Germany, the Tile classification adopted by the Orthopaedic Trauma Association (OTA) is used most widely [16], e.g. in the German Pelvic Injury Register and indirectly in TraumaRegister DGU®. The latter uses for all injuries the Abbreviated Injury Scale (AIS), but for pelvic ring fractures, the AIS<sub>pelvis</sub> bases to some extent on the Tile/OTA classification that differs between 3 types of injuries: Type A: Stable injuries of the iliac wing, sacrum and coccyx, and anterior pelvic ring. Type B: Rotationally unstable, but vertically stable injuries of the anterior and posterior pelvic ring. And Type C: Rotationally and vertically unstable injuries with complete disruption of the posterior arch [16,17] (Fig. 2).

**Prehospital trauma care**

The prehospital management of multiple trauma patients with pelvic fractures used to include a physical examination of the pelvic ring for mechanical instability. But, Pehle et al. found out that a clinical examination only has a sensitivity of 44% and a specificity of 99% for detecting pelvic fractures [19]. This means that even mechanically unstable pelvic ring fractures Type B/C according Tile/OTA can be missed already on scene. Nowadays, however, it is accepted that early application of a pelvic binder provides mechanical stability of the pelvic ring and allows clot formation. This may prevent ongoing pelvic derived haemorrhage and the often-lethal trauma-induced coagulopathy. Thus, actual consensus statements propose that pelvic immobilization should be used routinely if there is any suspicion of pelvic fracture based on the mechanism of injury, symptoms and clinical findings [20,21]. Looking for the administration of fluids in the prehospital setting, in the actual literature, there is upcoming evidence that limiting the amount of fluids given by following a strategy of permissive hypotension during the initial resuscitation period may improve trauma outcomes [22–24]. In 2011, Hussmann et al. showed by TraumaRegister DGU® data, that increasingly preclinical volume led to a slight elevation of lethality as well as of transfused packed red blood cells concentrates (PRBCs) in multiply injured patients after severe pelvic trauma. As a result, they



**Fig. 2.** Overview of the frequency, types, and severity of pelvic ring fractures according to the Abbreviated Injury Scale (AIS) of TraumaRegister DGU® from 2002 to 2011. Source: Modified from Burkhardt et al. [18].

**Table 1**  
Vital parameters, infusion volume, and blood transfusions during the initial resuscitation period (pre-hospital phase and time from arrival in the emergency department until arrival on ICU) in relation to the fracture type of the pelvic ring according Tile/OTA fracture classification.

		Type of pelvic ring fracture according Tile's/OTA fracture classification			Overall test	Pair-wise comparison			
		Total	Type A	Type B		Type C	P-Value (A vs. C)	P-Value (B vs. C)	P-Value (A vs. B)
Pre-hospital phase	Systolic blood pressure [mmHg, mean $\pm$ SD]	109 $\pm$ 31 (n=227)	120 $\pm$ 26 (n=59)	113 $\pm$ 31 (n=73)	100 $\pm$ 32 (n=95)	<0.001	<0.001	0.005	n.s.
	Ratio of patients in shock in the field (systolic blood pressure <90 mmHg) [%]	19.4 (n=227)	11.9 (n=7)	16.4 (n=12)	26.3 (n=25)	0.065	n.s.	n.s.	n.s.
	Heart rate [beats per min., mean $\pm$ SD]	99 $\pm$ 23 (n=231)	91 $\pm$ 18 (n=62)	101 $\pm$ 20 (n=71)	102 $\pm$ 27 (n=98)	0.006	0.003	n.s.	0.006
	Oxygen saturation [%, mean $\pm$ SD]	93 $\pm$ 10 (n=230)	94 $\pm$ 6 (n=53)	92 $\pm$ 8 (n=65)	91 $\pm$ 13 (n=81)	0.578	n.s.	n.s.	n.s.
	Infusion volume (crystalloids + colloids) [mL, mean $\pm$ SD]	1464 $\pm$ 1032 (n=258)	1072 $\pm$ 881 (n=67)	1608 $\pm$ 1096 (n=79)	1596 $\pm$ 1017 (n=112)	<0.001	<0.001	0.953	<0.001
Emergency department (ED)	Systolic blood pressure [mmHg, mean $\pm$ SD]	115 $\pm$ 27 (n=304)	123 $\pm$ 25 (n=69)	115 $\pm$ 23 (n=103)	111 $\pm$ 31 (n=132)	0.013	0.004	n.s.	n.s.
	Ratio of patients in shock on arrival in ED (systolic blood pressure <90 mmHg) [%]	12.2 (n=304)	4.3 (n=3)	8.7 (n=9)	18.9 (n=25)	0.005	0.005	0.039	0.366
	Heart rate [beats per min., mean $\pm$ SD]	91 $\pm$ 21 (n=297)	87 $\pm$ 19 (n=68)	92 $\pm$ 20 (n=100)	93 $\pm$ 22 (n=129)	0.143	n.s.	n.s.	n.s.
	Infusion volume ED to ICU (crystalloids + colloids) [mL, mean $\pm$ SD]	2884 $\pm$ 2471 (n=290)	1991 $\pm$ 1975 (n=67)	2645 $\pm$ 2438 (n=103)	3587 $\pm$ 2565 (n=120)	<0.001	<0.001	<0.001	0.118
	Packed red blood cell concentrates ED to ICU [units, mean $\pm$ SD]	3.4 $\pm$ 7.2 (n=344)	2.1 $\pm$ 5.7 (n=42)	3.0 $\pm$ 6.2 (n=54)	4.5 $\pm$ 8.5 (n=83)	<0.001	<0.001	n.s.	0.005
	Fresh frozen plasma ED to ICU (FFP) [units, mean $\pm$ SD]	3.0 $\pm$ 6.6 (n=344)	1.7 $\pm$ 4.9 (n=37)	2.7 $\pm$ 6.3 (n=52)	3.8 $\pm$ 7.5 (n=73)	0.010	0.003	n.s.	n.s.
Total initial resuscitation period	Total infusion volume during the initial resuscitation period (crystalloids + colloids) [mL, mean $\pm$ SD]	4626 $\pm$ 3079 (n=222)	3173 $\pm$ 2613 (n=57)	4677 $\pm$ 2976 (n=72)	5476 $\pm$ 3121 (n=93)	<0.001	<0.001	0.061	<0.001

Source: Modified from Burkhardt et al. [12].

recommended a moderate prehospital volume replacement, especially in polytraumatized children [24,25]. By matching the German Pelvic Injury Register with the TraumaRegister DGU<sup>®</sup>, for the first time, statements were feasible about the prehospital fluid management for different Tile/OTA types of pelvic-ring fractures for the German Pelvic Injury Register [12,26]. In summary, both patients with mechanically unstable pelvic-ring fracture types B and C showed significantly worse vital signs compared with type A, demonstrating a higher ratio of patients in shock already in the field for both of them. This higher physiological instability was related to administration of significantly higher volumes of crystalloids and colloids in fracture types B and C. Approximately 1.600 mL in sum of both, crystalloids and colloids, were administered in types B/C in a mean time period from accident to hospital arrival of about 73 min (see Table 1). These findings clearly show the actual dilemma of fluid resuscitation in pre-hospital trauma care, i.e. the discrepancy between expert consensus based restraint fluid administration and the recent practice of massive resuscitation [27].

### Trauma room management

Once arrived in the trauma room, the initial management of multiple trauma patients should always adhere to Advanced Trauma Life Support (ATLS<sup>®</sup>) principles and undergo the primary survey of airway (A), breathing (B), circulation (C), neurologic status (D; disability) and core temperature (E; environment) [28]. For patients with pelvic fractures, it is of pivotal interest to what extent the pelvic fracture contributes to a life-threatening blood loss requiring rapid surgical interventions or to a simple pelvic fracture that can be treated conservatively. Haemorrhage in trauma is aggravated and complicated by early trauma-associated coagulation disorders. This acute traumatic coagulopathy (ATC) has been described as a hypocoagulable condition developing in the immediate post-injury phase and resulting in uncontrolled non-surgical bleeding [29,30]. As we saw in not yet published data, almost every second multiple trauma patient with pelvic fracture revealed an apparent coagulopathy upon trauma room arrival. Increasingly pelvic ring instability resulted in more frequent ATC, i.e. 36.1% in type A, 50.4% in type B, and 53.1% in type C. In parallel, rates for massive blood transfusion, defined as  $\geq 10$  units of PRBCs

within 24 h, rose as well (8.3% in type A, 13.3% in type B, and 18.5% in type C). In the pelvis-specific trauma algorithm by Tscherne and Pohlemann, the so called “Complex Pelvic Fracture Module”, as well as in the ATLS<sup>®</sup> Pelvic Fracture Algorithm, the vital parameters as well as the response to administered fluid or blood products determine the next therapeutic step and massive fluid resuscitation reflects a central statement (Fig. 3) [31,32]. Regarding the results from the intersection set out of TraumaRegister DGU<sup>®</sup> and German Pelvic Injury Register data, within the time from arrival in the emergency department until arrival on ICU, an average of  $3587 \pm 2565$  mL of crystalloids and/or colloids followed by  $4.5 \pm 8.5$  units of PRBCs and  $3.8 \pm 7.5$  units of fresh frozen plasma was administered in the selective group of type C fractures. These high values of fluid given by confirmed that massive fluid resuscitation also in the in-hospital phase still reflects the recent practice in multiple trauma patients with life-threatening pelvic disruptions and that low-volume resuscitation seems not yet accepted in managing this special patient entity at least in Germany [12]. Thus, fluid management for trauma, not only for pelvic fractures, remains a controversial area and further research is mandatory. Finally, besides quantities of intravenous fluid resuscitation the question between crystalloids or colloids has newly become main topic of discussion and the future authorisations for hydroxyethyl starch must be awaited too [33].

### Day-one-surgery or damage control surgery

Achieving haemostasis of pelvic haemorrhage focuses on treatment modalities that minimize pelvic clot disruption and stop ongoing bleeding. In parallel to the stabilization of mechanically unstable pelvic ring fractures to generate a counter pressure at least for the venous bleedings by pelvic slings, pelvic binders, external fixator and/or pelvic C-clamp as well as internal osteosynthesis, haemostasis can be performed by pelvic packing or pelvic angiography and embolization [34–36] (Fig. 4). There is international consensus that mechanical stabilization of the pelvic ring by external fixator and/or pelvic C-clamp as part of Damage Control Surgery within 24 h after trauma decreases shock and mortality [5,6,31,34,35]. But, there is ongoing debate on the adequate therapeutic strategy in case of non-responding patients and we have the two different technique camps, i.e. pelvic packing

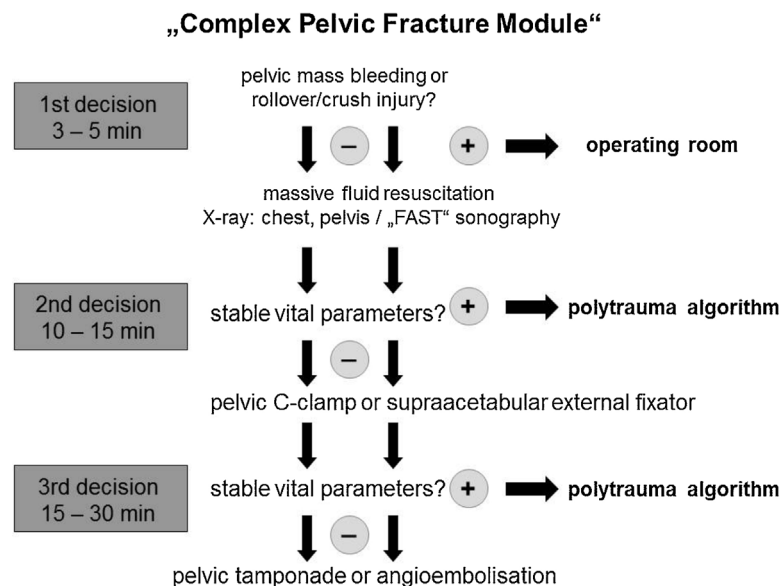
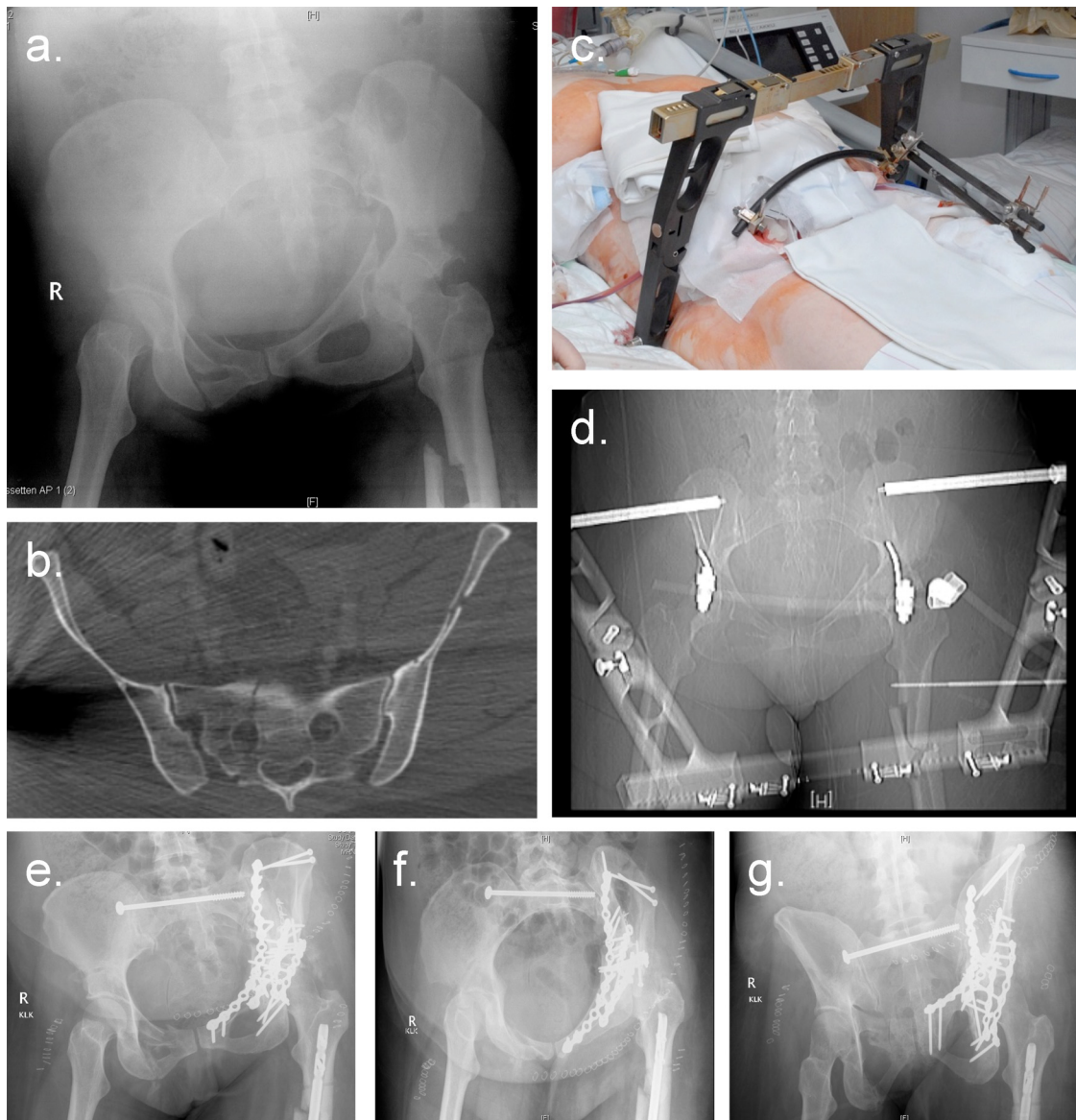


Fig. 3. Modified “Complex Pelvic Fracture Module” according to Tscherne and Pohlemann [29] as part of the trauma algorithm in the emergency department or trauma room.



**Fig. 4.** (a) and (b) Radiological a.p.-view and axial CT-scan of the pelvis of a 44 years old female after multiple trauma with a pelvic ring fracture type C according *Tile/OTA* (pubic fracture on both sides and right transforaminal sacral fracture) in combination with a left acetabular fracture. (c) and (d) Clinical picture and CT scout view after application of the C-clamp and additional supra-acetabular external fixator to stabilize the mechanically unstable pelvic ring as emergency procedure. (e)–(g) Radiological a.p.-, inlet- and outlet view after changeover to internal osteosynthesis of both, pelvic ring and acetabular fracture as well as retrograde nailing of the left femur.

or pelvic angio-embolization [37]. Whereas pelvic packing has its origin in Germany and Switzerland, angio-embolization is more frequent in the United States. Nevertheless, according to the actual literature, neither one of both techniques reflects higher levels of evidence, but a paradigm shift can be observed over the time. This means that in Europe pelvic embolization becomes frequently more used, and in contrast in the United States pelvic packing is more and more often advocated by trauma surgeons [38,39]. Noteworthy, there is a clear need for a prospective randomized study preferable in a multicentre setting.

### Summary

Haemorrhage from pelvic fractures remains a significant factor contributing to an even nowadays unacceptably high mortality. Holstein et al. found out that 62% of all patients who did not survive a pelvic disruption died because of massive bleeding from the pelvic region [10]. Thus, prevention of exsanguination still poses a

major challenge in the management of multiple trauma patients with pelvic fractures. Regarding the literature, there is a clear actual dilemma of initial fluid resuscitation, not only of multiple trauma patients with pelvic fractures, that is characterized by the discrepancy between expert consensus based low-volume fluid administration and the recent practice of massive resuscitation in pre-hospital and emergency-room trauma care at least in Germany. What makes this all the more regrettable is the fact that the early studies about limiting the amount of fluids given by may improve trauma outcomes. Finally, fluid resuscitation for trauma remains a controversial area and further research is mandatory.

### Future directions

The linkage of the German Pelvic Injury Register and the TraumaRegister DGU<sup>®</sup> enabled new insights into medical practices for multiple trauma patients with pelvic ring fractures including

initial fluid resuscitation and incidence of traumatic coagulopathy [12,26]. Future considerations and developments of both registries should take place in close consultation with the aim of benefiting from complementary data. A promising and beneficial effect for a better outcome after pelvic trauma in the future may also be the result of increasing proliferation of commercial pelvic binders with routine pelvic immobilization at the crash site. The same is true for the high expectations in the new organization of trauma care in Germany since the inauguration of the TraumaNetzwerk DGU® of the German Trauma Society in 2009. Another promising approach may be the critical reassessment of the current ATLS® classification of hypovolaemic shock that is the final common pathway in the deaths attributable to severe pelvic trauma, as well as the just in time coagulation management e.g. by thromboelastometry (ROTEM®)-guided administration of coagulation factor concentrates [40,41]. Last but not least, pelvis-specific trauma courses with the opportunity to train surgeons to reduce blood loss in severe pelvic ring injuries, e.g. pelvic packing by the help of a pelvic emergency simulator, or in general DSTC™ courses (DSTC = Definitive Surgical Trauma Care), can help to prepare surgeons for the rare but highly demanding emergency situations not only for managing life-threatening pelvic traumas [42].

### Conflict of interest

For this study, no specific financial support including any institutional funds was used. Each author certifies that he or she, or a member of their immediate family, has no commercial associations (e.g. consultancies, stock ownership, equity interest, patent/licensing arrangements, etc.) that might pose a conflict of interest in connection with the submitted article.

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