The sequence of the treatment of combined fractures of the pelvis, spine, and extremities in polytraumatized patients

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‘Damage control’ is the therapeutic strategy in the treatment of polytraumatized patients and aims at securing vital functions and controlling bleeding with a favorable effect on the post-traumatic immune response.

The post-traumatic immune dysfunction is based on a disturbed balance between immunostimulatory and anti-inflammatory mechanisms. The extent of the immunological ‘second hit’ can be limited by delaying deferrable surgical therapies until organ stabilization has been achieved by the treating surgeon.

Pelvic sling is easy to apply and noninvasive with effective pelvic reduction. Pelvic angiography vs pelvic packing are not antagonistic, but rather should be considered as complementary methods.

Operating as early as possible on unstable spinal injuries with confirmed or suspected neurological deficits by decompression and stabilization with a dorsal internal fixator.

Dislocations, unstable or open fracture, vascular involvement, and compartment syndrome are considered emergency indications. In extremity fracture treatment, primary definitive osteosynthesis is often dispensed with and instead, temporary stabilization with an external fixator is performed.

Polytrauma: challenges and management

Polytrauma (PT) caused by traffic accidents and falls are major cause of death and disability in patients under 50 years of age with immense socio-economic impact because of loss of productivity and medical or rehabilitation costs. According to the published data of the German TraumaRegister DGU®, 23,845 seriously injured trauma patients were registered in 2020. The average age was 54 years. Approximately 70% of the patients were men. The mortality rate was 8.6%. Regarding the age and gender distribution, international publications show an age peak between the 40th and 50th year of life and a predominance of the male gender (>60%). According to the literature, about 25% of severely injured PT patients are likely to have a pelvic injury, 30% spinal injury, and 65% injury of the extremity (1, 2, 3). However, the incidence of a combination of these injuries should be comparatively rare. More often, there is a concomitant injury to adjacent body structures such as the head and cervical spine, thoracic spine with thoracic trauma, or lumbar spine with abdominal injuries.

The treatment of patients with multiple injuries is challenging due to the different injury patterns and severity, complex immune reactions, and time-critical care. Post-traumatic immune dysfunction is due to a disturbed balance between immunostimulatory and anti-inflammatory mechanisms and can be strongly influenced by additional iatrogenic factors such as surgical interventions. While the initial trauma (‘first hit’) cannot be influenced, the extent of the immunological ‘second hit’ can be limited by delaying deferrable surgical therapies until organ stabilization (4, 5).

The care of severely injured trauma patients has changed in recent decades and is now based on strict guidelines. Algorithms such as the Advanced Trauma Life Support (ATLS®) or the European Trauma Course (ETC®) are intended to avoid errors and further standardize the rapid and unpredictable treatment of patients with multiple injuries (6).

Medical patient registries are an important tool for epidemiological questions, for monitoring the quality of patient care, analyzing risk factors, and making statements about the status of care practices (1).
Clinical classification of fractures

The Arbeitsgemeinschaft für Osteosynthesefragen (AO) classification was published in 1987 by Müller et al. and later supplemented by the AO. It represents the international standard for the classification of fractures. To date, modern fracture treatment and guideline development are based, among other things, on the 2018 version of the AO Fracture and Dislocation Compendium. Imaging diagnostics are required for the classification. The bone involved, the location of the bone, the fracture type, and the joint involvement result in an alphanumeric code that classifies the complexity and severity of the fracture (7).

Pelvic fractures are also classified according to the AO classification. It is based on the integrity or injury severity of the posterior pelvic ring that determines the stability of the pelvic fracture. The classification is based on three main groups: In type A fractures, the osseous and ligamentous integrity of the dorsal pelvic ring is intact. B injuries result in partial instability of the pelvis. C injuries are characterized by three-dimensional instability of the pelvic ring. The AO spinal classification is based on the spinal classification according to Magerl et al. (1994) and the Thoracolumbar Injury Classification and Severity Score and was developed in 2013. The AO spine classification divides injuries into three main types: compression fractures (A), distraction fractures (B) and translation fractures (C) (7).

The classification according to Tscherne and Oestern or Gustilo–Anderson is used to classify soft tissue injuries, for example, in open fractures and assess the risk of complications (8, 9).

Scientific assessment of multiple injury

According to the ‘Berlin definition’, PT involves at least two relevant body regions and at least one physiological problem.

The Abbreviated Injury Scale (AIS) was introduced in 1969 by the Association for the Advancement of Automotive Medicine. It assesses the severity of injuries in relation to the risk of mortality. Due to its complexity, the AIS is used less in clinical practice than in science and for quality assessment. AIS assigns a severity level between 1 (mild) and 6 (fatal) to each injury in different regions (head, face, thorax, abdomen, pelvis, extremities, and soft tissue injuries) (10). From this, severity scores such as the ‘Maximum AIS Severity Score’ (MAIS) or the ‘Injury Severity Score’ (ISS) can be calculated. The consensus of international publications defines organ trauma with AIS ≥ 3 (MAIS ≥ 3) points as serious injury and patients with an ISS ≥ 16 as severely injured (11).

Operative care concept

The therapeutic strategy in the treatment of polytraumatized patients is primarily aimed at securing vital functions and controlling bleeding, secondarily at a favorable modulation of the post-traumatic immune response. The concept of ‘damage control’ in the surgical care of severely injured patients with initial treatment on the day of the accident, including life-saving immediate operations, has proven to be favorable in this respect (12). Damage control surgery (DCS) refers to the minimally invasive and rapid control of bleeding, early stabilization of relevant unstable fractures, and thus aims to reduce the stimulation of humoral and cellular defense systems induced by instability, hematoma, and pain (13, 14). DCS has replaced the early total care. However, it is not always easy to decide which patients should be assigned to the graded treatment concept of damage limitation based on the systemic trauma response (15).

Secondary and tertiary surgery

In primary care, an overall therapeutic concept for the treatment of individual injuries is drawn up considering the injury pattern and the pathophysiological dynamics. The staged surgical treatment concept (DCS) aims to avoid an excessive iatrogenic ‘2nd hit’ through extensive surgical measures and thus to reduce post-traumatic inflammation (6, 16). To repair the soft tissue damage only second-look operations with post-debridement are performed in the vulnerable first days and repeated until well-perfused wound conditions are achieved. These interventions do not represent a relevant surgical burden but allow a reduction of systemic burden and mediator activation by removing foreign bodies tissue debris hematoma and necrosis. In the tertiary surgical phase, deferable operations such as definitive treatment of fractures are performed (17).

Timing

The exact timing of operations in the tertiary phase is difficult as there are no validated clinical indication parameters and must be done individually. On the one hand, operations that can be postponed should not be performed under any circumstances in the case of pronounced systemic inflammatory response syndrome (SIRS) in order not to additionally activate the systemic inflammatory processes. On the other hand, certain operations, such as the treatment of joint fractures, should nevertheless be performed early to achieve a satisfactory functional outcome. Basically, it can be said that a decrease in mediator activation, a negative balance, and a clear trend toward stabilization of organ functions make the performance of follow-up operations appear justifiable (17). Furthermore, there are numerous studies showing
that inflammatory parameters such as interleukin (IL)-6 or IL-10 provide important information about the current immune status (18).

**Pelvic fracture in polytrauma**

Pelvic fractures occur infrequently (about 3% of all fractures) compared to fractures of other body regions. The incidence of pelvic fractures increases to approximately 25% in PT patients after high-impact trauma. In the subgroup of traffic-related deaths, a pelvic fracture can be detected in up to 42% of cases. Severe fractures of the pelvic ring pose significant challenges to the entire trauma team in terms of life threat and functional outcome. The overall mortality of patients with pelvic fractures is between 5 and 10%, up to 60% for hemodynamically unstable pelvic fractures and as high as 70% for patients with open pelvic fractures due to loss of self-tamponade effect (19). Treatment algorithms focusing on volume resuscitation, mechanical stabilization of the pelvic injury, and clot management have led to improvements in the treatment and outcome of these mostly PT patients in recent years. Early identification of patients with pelvic fractures who are at the highest risk for pelvic bleeding is essential. Generally, for an injury that increases the bony volume of the pelvis (‘open fractures’), the likelihood of significant bleeding is much greater than in injuries that decrease the volume of the pelvis (‘lateral compression fractures’). However, severe bleeding can occur in all pelvic fracture patterns, and unfortunately, there is a poor correlation between the radiologically assessed severity of the pelvic fracture and the need for immediate hemostasis (20). Therefore, the physiological condition of the patient rather than the pelvic radiograph should be the determining factor for early resuscitation. Different parameters for the assessment of hemorrhage are suggested in the literature: sequential measurements of base deficit, lactate level, hypotension (systolic blood pressure < 100 mmHg) hematocrit ≤ 30, a pulse of ≥130, a displaced obturator ring fracture, and a diastasis of the pubic symphysis are good predictors of major pelvic hemorrhage (21).

**Pelvic sling**

Pelvic sling is tied around the pelvis at the level of the greater trochanter to apply pressure to the pelvic ring during internal rotation of the legs. It is easy to apply, inexpensive, and noninvasive. In theory, all the benefits of the pelvic binder can also be achieved with a simple bed sheet, although one study concluded that the pelvic binder was superior to the sheet in treating significant pelvic bleeding. However, the pelvic binder must be positioned correctly for this purpose. Biomechanical studies on cadavers provided evidence of effective pelvic reduction with trusses tensioned to 140–200 n for ‘open

**Supra-acetabular external fixation and pelvic C-clamp**

Anterior external fixators for the pelvis are easy to use and quick to apply (15–20 min). The bolts are anchored in the iliac crest or supra-acetabular bone. They are most effective for type B fractures (open book fractures and lateral compression fractures). For type C fractures (vertical shear fractures), they can stabilize the anterior pelvic ring in addition to a C-clamp. However, experimental studies have shown that it produces little change in pelvic volume, so external fixation primarily contributes to hemostasis by reducing fracture motion and allowing stable clot formation. Disadvantages of external fixation include the inability to adequately stabilize the posterior pelvic ring and infections at the insertion site, which may interfere with subsequent definitive open reduction and internal fixation.

The pelvic C-clamp can be used posteriorly for the direct reduction of vertically and rotationally unstable fractures. By exerting transverse compression over the sacroiliac joint, the basis for effective pelvic tamponade is established. It was concluded that the combination of a C-clamp and pelvic packing can effectively control pelvic bleeding in patients in the extremis. The surviving patients showed stabilization of blood circulation and consolidation of oxygenation levels 6 h after the C-clamp. Five hours after the use of the C-clamp, the number of blood units required decreased significantly. However, the use of the C-clamp in the pelvis is limited to a subset of indications and often requires the addition of an anterior external fixator or plate for type C fractures. The C-clamp is not applicable for fractures of the ilium and transiliac fracture dislocations.

**Pelvic angiography vs pelvic packing**

Two different fundamental treatment modalities for hemodynamic instability due to pelvic fractures are discussed: Angiography with sequential embolization to control arterial bleeding vs pelvic packing, which mainly controls venous bleeding and bleeding from the fractures. These controversies are based, among other things, on the different development of trauma systems in European
countries and North America: in the Anglo-American region, arteriography, which is increasingly available, has become the first-line treatment for hemodynamically unstable pelvic trauma patients over the last decade. In European countries, many trauma surgeons are trained in orthopedic surgery and are familiar with pelvic stabilization techniques and pelvic packing as DCS. Ertel et al. reported success in controlling both arterial and venous hemorrhage by tightly packing the pelvis. The transabdominal approach to pelvic packing has the disadvantage of opening the potentially intact peritoneum with the disruption of the pelvic hemotoma, thus interrupting the tamponade effect of the retroperitoneal space. To minimize these disadvantages, the retroperitoneal method was described. The presacral and retroperitoneal regions are packed from posterior to anterior on each side. However, there are also disadvantages of pelvic packing. Compared with angiography, it is a relatively invasive procedure that may not be fully effective in controlling bleeding from large-caliber arteries, and there is a need for reoperation to remove the packs 24–48 h after the initial procedure (20).

Establishing gold standard treatment guidelines for either approach is difficult because of the multisystemic nature of the injury. Our group has previously indicated that these two treatment modalities ‘are not antagonistic but rather should be considered as complementary methods’. In our experience, signs of persistent bleeding after mechanical pelvic stabilization and pre-peritoneal pelvic packing indicate the need for postoperative pelvic angiography. Embolization of residual arterial bleeding can then be performed on the way from the operating theater to the intensive care unit (ICU) in a patient with a more stable hemodynamic status (22). This concept of pre-peritoneal pelvic packing external fixation of the pelvic ring injury and secondary angioembolization is not new and was previously described by Burlew et al. Here in 10% of 75 patients with severe pelvic fractures and life-threatening bleeding, angioembolisation was performed after surgery and none of these patients died due to pelvic bleeding (23).

Spine trauma in multiple injured patients
Looking at the incidence of relevant spinal injuries, it is assumed that there are about 10,000 relevant injuries per year. Twenty-five percent of the injured suffered a spinal injury in the context of multiple injuries. On the one hand, the thoracolumbar transition represents the transition from the physiological kyphosis of the thoracic spine to the lordosis of the lumbar spine, but on the other hand, it is generally more susceptible to fractures due to the omission of the thorax in the sense of a ‘free-standing’ lumbar spinal segment. Epidemiological studies have described the highest incidence of fractures in the thoracolumbar transition (TH11–L2) at 68.8%, followed by injuries to the thoracic spine (TH1–TH10) at 18.3% and the lumbar spine (L3–L5) at 12.9%. In 5%, several spinal segments are injured (24). Since the line of gravity lies perpendicular in front of the thoracic spine, compression fractures of the vertebral bodies are frequently observed, especially in this section of the spine. However, B (flexion-distraction) and C (rotation) injuries of this spinal segment also occur in the context of high-impact traumas. Traumatic injuries to the spine are often combined injuries to the bony and disco-ligamentous structures and ultimately to the neural structures. For this reason, a differentiated approach is required in both diagnostics and therapy (25). In addition to the bony injury, which can be quickly detected radiologically in the native X-ray and in computed tomography, a search must be made for any injuries to the disc ligament apparatus. In addition to the exact classification, biomechanical aspects must be considered when planning the therapeutic approach, whether conservative or surgical. Neurological complications in the sense of complete or incomplete paraplegia occur in about 20% of all cases of spinal injuries, with decreasing frequency in the cervical (30%), thoracic (20%), and lumbar (10%) spine (26). Vertebral injuries may be associated with neighboring injuries. For example, severe cervical spine injuries (AIS ≥ 3) are significantly more often associated with severe traumatic brain injury (initial Glasgow Coma Scale (GCS) < 9) than milder cervical spine injuries. Severe cervical spine injuries correlate significantly more often with severe chest trauma (AIS ≥ 3; ≥ 96%). The same applies to severe abdominal injuries in patients after severe lumbar spine trauma (27). Regarding the treatment strategy, the literature recommends operating as early as possible on unstable spinal injuries with confirmed or suspected neurological deficits, with malposition, where neurological deficits can probably be prevented or improved by reduction, decompression, and stabilization (‘day 1 surgery’). In the cervical spine, halo-fixator or ventral stabilization procedures can be used as primary surgical methods. Unstable thoracolumbar spinal injuries without neurology should be treated surgically in PT. Dorsal internal fixator should be used as the primary surgical method for thoracolumbar spine injuries. Stable spinal injuries without neurology should be treated conservatively (28).

Accompanying injury to the extremities – secondary negligible or relevant combined injury?
According to the data of the TraumaRegister DGU® of the German Trauma Society, more than 65% of all PT involve injuries to the extremities and/or pelvis (AIS > 2). Depending on the location of the injury, there may be relevant blood loss of up to 2000 ml (29) caused by vascular ruptures in the soft tissues or by the fracture itself (29, 30). Acute compartment syndrome occurs
when the volume within the myofascial compartment exceeds the level of connective tissue elasticity due to the accumulation of blood and tissue fluids following injury or reperfusion. The increased pressure leads to progressive ischemia with necrosis and potentially irreversible damage to all myoneural tissue (31). Dislocations, unstable or open fracture, vascular involvement, and compartment syndrome are considered emergency indications (32).

‘Damage control’ is a strategy for the care of severely injured patients with the aim of minimizing secondary damage and maximizing the patient’s outcome. In the area of extremity fracture treatment, primary definitive osteosynthesis is therefore often dispensed with and instead, due to the smaller intervention, temporary stabilization with an external fixator is performed. Controversial treatment strategies are practiced and published for the management of long bones in PT (32). The following recommendations can be found in the literature: Isolated and multiple shaft fractures of long tubular bones can be stabilized in PT, both primary-definitive and primary-temporary and secondary-definitive. For the definitive treatment of a femoral shaft fracture in PT patients, locking intramedullary nailing should be performed as the surgical procedure of choice. Unstable proximal tibial fractures and tibial plateau fractures can be stabilized – tibial shaft fractures should be stabilized primarily. In this context, it should be emphasized that the individual biological conditions (e.g. age), the overall injury severity, but also severe of the additional injuries (e.g. a severe craniocerebral trauma), the necessary operation time, compensated disturbances of vital parameters, and the physiological condition of the patient (metabolism, coagulation, temperature, etc.) should be included in the decision-making (14, 16). The decision to amputate or to preserve the limb in cases of severe injury should be made as an individual decision. In rare cases and in extremely severe injuries, amputation may be recommended (33).

In addition, it is recommended that surgically technically challenging fractures (such as condylar fractures) in PT patients be stabilized provisionally first and reconstructed definitively secondarily.

**Reality analysis of a Lever-1 trauma center from 2018 to 2021**

We retrospectively studied a cohort of severely injured trauma patients admitted to the trauma bay of the level-1 trauma center of Frankfurt University Hospital between 2018 and 2021. All trauma patients in the emergency department were treated according to the ATLS® (American College of Surgeons, Chicago, IL, USA) standard and the PT guidelines.

All patients with severe trauma and who suffered a pelvic injury min. AIS ≥ 2 were included in the study. Participating patients had to be ≥ 18 years of age. All clinical data were prospectively collected as part of the quality documentation of our in-house trauma registry. This database contains information on demography, injury patterns, comorbidities, preclinical and clinical management, and intensive care progress, as well as significant laboratory findings and outcome data. Patients who met these inclusion criteria were analyzed in terms of injury patterns and clinical data on treatment before and during hospitalization, especially about factors influencing treatment processes and decisions and possible treatment algorithms to be derived.

Our study followed the STROBE guidelines for observational studies (Strengthening the Reporting of Observational Studies in Epidemiology) and the RECORD guidelines for observational studies (Reporting of studies Conducted using Observational Routinely Collected Data) [22,23]. This study was conducted after approval by the Institutional Review Board of the University Hospital of the Goethe University Frankfurt (EV 89/19).

**Statistical analysis**

Continuous, normally distributed variables were summarized as mean ± s.d., while categorical or continuous variables with skewed distribution were summarized as medians with interquartile ranges (IQR). The P-values for categorical variables were derived from Fisher’s two-tailed exact test, and for continuous variables from the Mann–Whitney U test or the Kruskal–Wallis test if more than two groups were compared. Significant values were adjusted by the Bonferroni post-hoc test. P-value < 0.05 was considered statistically significant (*P < 0.05; **P < 0.01; ***P < 0.001). Values are presented as mean for continuous variables and as percentage for categorical variables. All analyses were conducted using Statistical Package for Social Sciences (SPSS for Mac©), version 27 (SPSS Inc., Chicago, IL, USA).

**Results**

During the 4-year period, 1153 patients were admitted to the trauma bay of our level-1 trauma center with suspicion of severe multiple injuries. Of these patients, 94 patients suffered a relevant pelvic injury (P) (AIS ≥ 2). Of these, 11 (13.8%) had a co-occurring spinal injury (S), 38 (40.4%) had a simultaneous limb injury (Ex), and 32 (43.0%) suffered a combination of pelvic, spinal, and limb injuries.

The median (IQR) age of the patient cohort was 43 (29–61) years, 18 of them were ≥65 years old, and 74.5% were male.

As shown in Fig. 1, 75 (79.8%) patients were admitted after an accident, 18 (19.1%) after a suicide attempt, and 1 (1.1%) after interpersonal violence. One-third (31 (33.0%)) of the patients suffered injuries after a fall from a greater height. About one-half were involved in a traffic accident,
mainly car drivers (13 (13.8%)), followed by pedestrians (15 (16.0%)), motorcyclists (12 (12.8%), and cyclists (6 (6.4%)). One-third suffered a fall from a greater height (31 (33.0%).

Of the 94 included patients, only 52 (55.3%) were suspected of having a pelvic injury. A pelvic sling was applied to almost all (51 (54.3%)) of these patients. This also corresponds to the data on the individual cohorts and the remaining injury patterns: As shown in Table 1, the actual injury pattern was correctly assessed preclinically in only about half of the patients.

All patients with pelvic fractures, whether with or without additional spinal and limb injury, had relative tachycardia but normotension (RRsys 110–124 mmHg) as the first sign of hypovolemia. With initial signs of hypovolemia, an average volume requirement of 875–1167 mL and a requirement for catecholamines of up to 31%, only 9.1–23.1% of patients received tranexamic acid preclinically.

In the P, P+Ex, and P+S+Ex groups, 3–4 patients required prehospital resuscitation. Even more patients (18.2% (P+S) – 50.0% (P+S+Ex)) were already intubated and ventilated preclinically.

Table 2 shows the data collected within the hospital after arrival at the trauma bay. Based on the ISS, all groups include severely injured patients (ISS ≥ 16). Although the patients in group P did not suffer any spinal or extremity injuries, they did suffer relevant injuries in other organ systems, like thoracic injury, as shown by the AIS.

Figure 2 shows the distribution of fracture type stratified by pelvic (A), spine (B), and extremity injury (C). Among pelvic injuries, type-B fractures (37 (39.4%)) were the most common after type-C (26 (7%)%) and type-A (21 (22.3%)). 27 (28.7%) patients suffered an acetabular fracture. Fractures of the spine most frequently affected the thoracic (18 (41.9%)) and lumbar spine (24 (55.8%)), less frequently the cervical spine (11 (25.6%)). Further, (9 (20%)) suffered fractures on multiple segments. Combined limb injuries (only fractures of the femur, tibia, humerus, forearm) were present in 70 (74.5%) cases – of which the upper limbs were involved in 55.7% (n = 39) and the lower limbs in 67.1% (n = 47) whilst 22.9% (n = 16) suffered a combined limb injury.

Table 2 shows that the GCS of the P+Ex and P+S+Ex group (GCS median 3) was significantly worse than that of the other group (GCS median 14–15). Regarding the vital signs HB and RRsys as well as the laboratory parameters hemoglobin and base excess, there was no relevant difference between the groups.

Extracorporeal resuscitation was performed or continued in the trauma bay in 9.1–30.8% of cases. In 2–8 patients, a pelvic sling was applied after the primary survey in the hospital. Depending on the group, the patients spent between 2.9 and 12.6 days in intensive care – correspondingly longer with increasing injury severity (measured by ISS).

The outcome was worse according to injury severity in the P+S+Ex group with a high proportion of severely disabled patients (10 (31.2%)).
Figure 2 shows that the final fracture treatment is performed from day 1 to 19 after trauma. Osteosyntheses of pelvic and spinal fractures were mainly performed within the first week. Most extremity fractures were operated on between days 5 and 14 after trauma.

**Discussion**

The patient and injury structure of our study corresponds to that of the literature, whereby the main causes of the present fractures are traffic accidents and falls from heights. As already mentioned in the literature, the demographic change toward an aging society also influences the age structure of trauma patients. Although the group of accident victims after a high-energy trauma still includes younger, male patients around the age of 45 on average, the age structure of trauma patients is changing. After all, about 20% of the patients studied here are 65 years and older. The increasing treatment of older severely injured PT patients in the future will pose an additional major challenge (1, 34). This group of people differs from younger patients in their immune response, regenerative capacity, and resilience. The field of geriatric PT is still new, and detailed studies on the impact of the altered immune response are not yet available to a sufficient extent to design deviating therapeutic concepts (35).

Pelvic B fractures were the most common fractures in our trauma patients. However, they were closely followed by pelvic A and C fractures and acetabular fractures. Ventral avulsion and open book fractures played an important role. Of patients with pelvic fracture 21.3% were treated

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**Table 2** Clinical findings in trauma bay and therapy decisions stratified by injury pattern. Data are presented as mean ± s.d. and median (IQR) or as n (% of total n).

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AIS, Abbreviated Injury Scale; BE, base excess; CAT, catecholamine; CPR, cardiopulmonary reanimation; EC, erythrocyte concentrate (1 pc = 250 mL); Ex, extremity fracture; Hb, hemoglobin in mg/dL; RR, heart rate in bpm; ICU, intensive care unit; ISS, Injury Severity Score; P, pelvic fracture; RR_syst, systolic blood pressure in mmHg; S, spine fracture.
in DCS. Of these, 20 patients received a supra-acetabular external fixator, 18 patients received a pelvic packing, and 2 patients received angiographic embolization. None of the patients was treated with a C-clamp. In all cases, direct stabilization of the anterior pelvic ring in combination with pelvic packing was sufficient to bridge the first phase of the patient’s post-traumatic stabilization. In two cases, angiography was required after surgery due to persistent active bleeding. Only in a few cases did the spinal injuries have to be stabilized in a DCS in combination with a pelvic fracture. In accordance with the guideline, only dorsal stabilization with laminectomy – if necessary – was performed. Dislocated, luxated, or open fractures of the long tubular bones (such as humerus, radius, femur, or tibia) were treated with an external fixator in most cases. Only in a few cases was definitive treatment performed by means of intramedullary osteosynthesis of the femur or tibia. Here, our clear recommendation is to perform such a definitive osteosynthesis only in hemodynamically stable patients without relevant thoracic trauma (AIS ≤ 2) and moderate, non-compromising concomitant injuries to avoid a 2nd hit and to avoid systemic complications such as thromboembolic events. Deferrable surgery should be performed outside the vulnerable phase, as shown in Fig. 3 (28, 36).

Mortality was significantly increased in all groups except P+S. This is mainly because even the supposedly less severely injured group P included two patients with severe traumatic brain injury and four patients with severe thoracic trauma. This is also the case for the other groups. The mortality of these patients cannot be attributed to pelvic injury alone, although this certainly plays a significant role (21). The mortality of pelvic injuries is high and, as our data show, is less influenced by additional spinal and limb injuries, but is influenced by injuries to other relevant organ systems, as present in PT. It is difficult to provide a universal roadmap for the care of combined injuries of the pelvis, spine, and extremities. Based on the injury patterns shown, pelvic and spinal injuries rarely occur alone in the context of a high-risk trauma, but very often in combination with severe injuries to adjacent structures such as the head, thorax, or abdomen. These can also cause a critical or life-threatening condition in the patient and thus have a relevant influence on therapy decisions and their temporal course (27).

Numerous parameters are described in the literature that should be indicators for a surgical therapy decision in the context of PT and especially in the presence of a pelvic fracture. These include systolic blood pressure, heart rate, state of consciousness (GCS) or hemoglobin level and base excess. As our analysis shows, most of the patients’ parameters in all groups are within or at the edge of the reference ranges. Only the pulse, GCS, and BE in the groups with combined injuries are outside the norm and indicate hypovolemia or loss of consciousness (37, 38).

Basically, the extended recommendation of the ‘treat first what kills first’ principle applies here, ‘treat first what compromises most’. The aim is to get the severely injured person stabilized and mobile as quickly as possible to prevent complications and improve the outcome (39). Therefore, our recommendation is to perform pelvic and vertebral treatments as soon as possible to minimize complications while the patient’s condition is acceptable. Performing surgery in the vulnerable phase always remains an individual decision. Whether an unstable vertebral fracture, an unstable pelvic fracture, or an unstable limb is treated first is decided in our clinic based on an individual assessment of the patient, the fracture morphology, and the expected outcome (40). Limb injuries of the large and proximal bones such as the femur, tibia, and humerus are treated before distal fractures such as the radius. Extremity fractures that are primarily stabilized with a fixator are predominantly only subjected to a change of approach during the procedure and thereafter.

**Conclusion**

Post-traumatic immune dysfunction is due to a disturbed balance between immunostimulatory and anti-inflammatory mechanisms. Deferrable operations should be performed outside the vulnerable phase. Damage control is the therapeutic strategy in the treatment of polytraumatized patients and aims to secure vital functions, control bleeding, and favorably influence the post-traumatic immune response.

The pelvic sling is easy to use and non-invasive with effective pelvic reduction. Pelvic angiography and pelvic packing are not opposites but should be considered complementary methods.

Spinal injuries are often associated with adjacent injuries. Pelvic and spinal injuries rarely occur alone, but very often in combination with severe injuries to adjacent...
structures such as the head, thorax, or abdomen. These injuries, some of which are life-threatening, have a relevant influence on therapy decisions and their timing.

Unstable spinal injuries with confirmed or suspected neurological deficits should be treated as early as possible by decompression and stabilization with a dorsal internal fixator.

Dislocations, unstable or open fractures, vascular involvement, and compartment syndrome are considered emergency indications. In the treatment of limb fractures, primary definitive osteosynthesis is often omitted and temporary stabilization with an external fixator is performed instead.

ICMJE conflict of interest statement
C R Schindler, R Sturm, J Horàf, J Marzi, and P Störmann declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Compliance with ethical requirements
This study has been conducted after approval by the Institutional Review Board of the University Hospital of the Goethe University Frankfurt (89/19).

Author contribution statement
PS designed the study, established the methods, revised the manuscript. CS collected data, carried out data analyses, obtained the ethical approval for human analyses, performed the statistical analysis, and wrote the first draft of the manuscript. IM critically reviewed the manuscript. RS and JH contributed intellectually to the completion of the study.

References
21. Davis DD, Foris LA, Kane SM & Waseem M. Pelvic Fracture 2022n. StatPears [Internet]StatPears PublishingLireaure Island (FL), USA. Available at:


