REVIEW ARTICLE

Multiple Trauma and Emergency Room Management

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SUMMARY

Background: The care of severely injured patients remains a challenge. Their initial treatment in the emergency room is the essential link between first aid in the field and definitive in-hospital treatment.

Methods: We present important elements of the initial in-hospital care of severely injured patients on the basis of pertinent publications retrieved by a selective search in PubMed and the current German S3 guideline on the care of severely and multiply traumatized patients, which was last updated in 2016.

Results: The goal of initial emergency room care is the rapid recognition and prompt treatment of acutely life-threatening injuries in the order of their priority. The initial assessment includes physical examination and ultrasonography according to the FAST concept (Focused Assessment with Sonography in Trauma) for the recognition of intraperitoneal hemorrhage. Patients with penetrating chest injuries, massive hemothorax, and/or severe injuries of the heart and lungs undergo emergency thoracotomy; those with signs of hollow viscus perforation undergo emergency laparotomy. If the patient is hemodynamically stable, the most important diagnostic procedure that must be performed is computerized tomography with contrast medium. Therapeutic decision-making takes the patient's physiological parameters into account, along with the overall severity of trauma and the complexity of the individual injuries. Depending on the severity of trauma, the immediate goal can be either the prompt restoration of organ structure and function or so-called damage control surgery. The latter focuses, in the acute phase, on hemostasis and on the avoidance of secondary damage such as intra-abdominal contamination or compartment syndrome. It also involves the temporary treatment of fractures with external fixation and the planning of definitive care once the patient's organ functions have been securely stabilized.

Conclusion: The care of the severely injured patient should be performed in structured fashion according to the A-B-C-D-E scheme, which involves the securing of the airway, breathing, and circulation, the recognition of neurologic deficits, and whole-body examination by the interdisciplinary team.

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The principal cause of life-threatening injuries in Germany is blunt trauma, predominantly from road traffic accidents of all kinds or falls from height (1). Furthermore, the demographic trend towards an aging population means that more elderly patients are suffering severe head injuries in falls from standing height (2).

The incidence of severe trauma in Germany (20 000 to 35 000 cases/year) is a subject of recent debate, but regardless of the actual numbers the management of these patients represents a challenge from the medical, logistical, and socioeconomic viewpoints. The treatment algorithms for severe trauma are continually reviewed and updated to take account of new research findings.

The aim of this review is to present the current state of knowledge on what we, the authors, see as central aspects of trauma management. To this end, we carried out a selective survey of the literature in the PubMed/Medline database to identify publications relevant to imaging in the emergency room, the Damage Control Surgery concept, and optimization of coagulation in the seriously injured. We included publications which, in our subjective opinion, have an important impact on diagnostic or therapeutic algorithms. Furthermore, this article presents some recent developments in the Trauma Network of the German Society for Trauma Surgery (*Deutsche Gesellschaft für Unfallchirurgie*, DGU), including the integration of rehabilitation facilities, and the newly revised S3 guideline.

Challenges in the emergency room

There is still no uniformly applied classification of severe trauma, very severe trauma, and multiple trauma. Internationally, patients with an Injury Severity Score (ISS) of 16 or higher (on a scale of 0 to 75) are defined as severely injured. A diagnosis of “multiple trauma” implies the presence of two or more separate injuries, at least one or a combination of which endangers the patient's life. Considerable costs are involved in maintaining the structures and staffing levels necessary for 24-h/365-day readiness to treat severely injured patients in the over 600 trauma centers throughout Germany.

The evidence-based interdisciplinary treatment guidelines (S3 Guideline Trauma Management [5]) and the verification of adequate structures and staffing levels in so-called certified trauma centers enable early

TABLE 1

Circumstances in which activation of the shock room team is recommended*

Physiological parameters	Injury patterns	Mechanisms of injury
Systolic blood pressure <90 mm Hg after trauma	Penetrating injuries of neck and trunk	Fall from height >3 m
Glasgow Coma Scale score <9 after trauma	Gunshot injuries of neck and trunk	Road traffic accident
Breathing disturbance/need for intubation after trauma	Fractures of more than two proximal bones	Frontal collision with intrusion of more than 50 to 75 cm
	Unstable thorax	Changes in velocity of delta >30 km/h
	Unstable pelvic fracture	Pedestrian/motorcycle collision
	Amputation proximal to hands/feet	Death of a passenger
	Injuries with neurological signs of paraplegia	Ejection of a passenger
	Open cranial injury	
	Burns >20% of grade ≥ 2b	

*Patients fulfilling any of these criteria should be admitted via the shock room (2).

hospital treatment of the seriously injured in all parts of the country.

The initial treatment of a patient with severe trauma is crucial for the long-term outcome. The “shock room” is the interface between prehospital management and inpatient care. The criteria for treatment in the shock room are based on the patient’s physiological parameters (recommendation grade A), the injury pattern (recommendation grade A), and the trauma mechanism (recommendation grade B) (Table 1) (5, 6). Depending on the care level of the hospital concerned, each member of the shock room team has clearly defined responsibilities (Table 2). It was recognized that implementation of standardized diagnostic and therapeutic algorithms is necessary to eliminate treatment errors, avoid overlooking important diagnoses, and cut out delay.

Various training courses in initial shock room management are available for both physicians and nurses, e.g. the Advanced Trauma Life Support (ATLS) program and the European Trauma Course. The training goal is to render shock room staff able to gather relevant information without delay or further risk to the patient and to treat life-threatening injuries. Such systems can improve the procedures in the shock room after their implementation, as has been shown for the ATLS (7). While no impact on overall mortality has yet been demonstrated, one study reported a reduction in the rate of death within 1 h after arrival at the hospital from 24.2% to 0% (8). Although participation in training of this nature by all members of staff seems a good idea, no high-quality studies have evaluated the influence of training on the mortality or other outcome parameters of severely injured patients (9).

The ATLS course contains elements of theoretical tuition but focuses mainly on practical exercises and simulations of shock room procedures. In the primary

survey, each patient is examined systematically according to the A-B-C-D-E scheme, in which the defined goals are:

- A – Airway: secure/establish airway, immobilize cervical spine
- B – Breathing: secure adequate gas exchange
- C – Circulation: secure adequate tissue perfusion
- D – Disability: identify neurological deficits, intoxication, etc.
- E – Environment: examine whole body of completely unclothed patient, keep patient warm, manage non-life-threatening injuries

Participation in such a course is not an obligatory component of specialist medical training in Germany, but in Switzerland, for example, physicians cannot obtain a specialist qualification in surgery without having attended a course. However, no German center can join the DGU Trauma Network without staff members having completed relevant training programs.

Control of bleeding

Hemorrhagic shock is one of the central problems in patients with multiple trauma and a common cause of death. Increasing clinical and research interest in the specific role of posttraumatic coagulopathy culminated in the foundation of the European Initiative Task Force for Advanced Bleeding Care in Trauma in 2004. The resulting guidelines, first published in 2007 and most recently updated in 2016 (10), state that the first step is to identify the source of bleeding. If the patient does not respond to nonsurgical measures (volume replacement, compensation of acidosis, etc.), surgical hemostasis is recommended. During the shock room phase the patient’s coagulation parameters (prothrombin time, partial thromboplastin time, thrombocyte count, fibrinogen and/or viscoelastic procedures) should be determined and any necessary corrective treatment

TABLE 2

Medical specialties required at local and regional trauma centers

Specialty	Local trauma center	Regional trauma center	Supraregional trauma center
Trauma surgery/orthopedics + special trauma surgery	X	X	X
Anesthesiology	X	X	X
Visceral surgery	X	X	X
General surgery	X	X	X
Radiology	X	X	X
Neurosurgery		X	X
Vascular surgery		X	X
Thoracic surgery			X
Otorhinolaryngology			X
Ophthalmology			X
Oral and maxillofacial surgery			X
Urology			X
Cardiac surgery			X
Pediatrics/pediatric surgery			optional
Gynecology			optional
Hand or plastic surgery			optional

initiated. However, improvement of coagulation must not be delayed by laboratory analyses.

The target systolic blood pressure in seriously injured patients with hemorrhagic shock is 80 to 90 mm Hg. In the presence of severe head injury, the systolic blood pressure should be kept >80 mm Hg. Restrictive volume replacement with the above-mentioned target values should be carried out using crystalloid solutions. Packed red cells (PRC) and fresh frozen plasma (FFP) should be transfused in a fixed ratio of 2:1 to attain hemoglobin concentration of 70 to 90 g/L. Alternatively, fibrinogen and PRC can be given. The initial dose of fibrinogen should be 3 to 4 g in the presence of pathological viscoelasticity or a plasma fibrinogen level <1.5 to 2.0 g/L.

The thrombocyte count should generally be $50 \times 10^9/L$; with persistent hemorrhage or in the presence of head injury the target is $100 \times 10^9/L$.

With regard to antifibrinolytic medication, early administration of tranexamic acid in the shock room is recommended for all patients with manifest or threatened hemorrhagic shock. Initial infusion of 1 g tranexamic acid over 10 minutes should be followed by administration of a further 1 g over the next 8 hours.

In patients with persistent bleeding and thrombocyte function disorders (disease-related or drug-induced), thrombocyte function should be determined and thrombocytes transfused if required. Administration of desmopressin in a dose of 0.3 µg/kg is reserved for patients with von Willebrand-Jürgens syndrome and those being treated with thrombocyte aggregation inhibitors.

Recombinant factor VIIa should be given to patients with heavy bleeding and persistent coagulopathy only after exhaustion of all alternative measures.

Imaging in the emergency room

The central challenge for the shock room team is swift identification and treatment of injuries requiring urgent intervention. Together with immediate treatment of intrathoracic trauma with implications for cardio-respiratory function, detection and treatment of intra-abdominal injuries are of vital importance in the care of severely injured patients (11). Focused Assessment with Sonography in Trauma (FAST) is the established primary diagnostic imaging examination. FAST is sufficiently sensitive for important intraperitoneal hemorrhage and can also yield information on the presence or otherwise of cardiac tamponade or hemothorax/pneumothorax. Secure insertion of a thoracic drain remains the fundamental therapeutic intervention in the acute phase of blunt thoracic trauma, while patients with penetrating thoracic trauma, massive hemothorax, and serious injuries of the cardiorespiratory organs receive emergency thoracotomy.

In hemodynamically unstable patients with demonstrated hemoperitoneum, immediate hemostasis by means of emergency laparotomy is indicated; in the case of negative FAST, extra-abdominal bleeding sources have to be excluded. The subsequent computed tomography (CT) scan with intravenous contrast medium in the hemodynamically stable patient is currently the most important procedure in the initial diagnostic

Figure 1:

Three-dimensional rendering of computed tomography in a multiple trauma victim with a type C pelvic fracture

work-up of severe trauma. Notwithstanding certain limitations in the visualization of lesions of the abdominal hollow organs, the pancreas, and the diaphragm, CT helps to paint a comprehensive and accurate picture of the patient's injuries.

Accordingly, CT is an indispensable component of the current algorithms (*Figure 1*). Retrospective analysis of data from the German national trauma registry, maintained by the DGU, showed that whole-body CT was associated with a higher survival rate in seriously injured patients with blunt trauma (12). The relative reduction in mortality was calculated as 13% on the basis of the Revised Injury Severity Classification and 25% using the Trauma and Injury Severity Score (12).

This is presumably due to a reduction in the number of relevant diagnoses that go undetected, along with the depiction of the overall injury pattern. The latter permits timely priority-oriented planning of further diagnostic and therapeutic procedures.

Nonsurgical management, Early Total Care, and Damage Control Surgery

Due in no small part to the dramatic improvements in abdominal imaging, nonsurgical treatment is currently standard in the management of hemodynamically

stable patients with no signs of hollow organ lesions after blunt trauma. Nevertheless, diagnostic laparotomy remains the procedure of choice for perforating abdominal injuries and in patients with clinical signs of peritonitis. There is currently no consensus on the importance of diagnostic or therapeutic laparoscopy in patients with severe trauma. Laparoscopy is not, at present, the clinical standard for the treatment of abdominal injuries. However, a recent analysis of the treatment and outcome data from the DGU trauma registry showed that laparoscopic diagnosis and intervention was carried out in 0.7% of a population of severely injured persons with abdominal trauma (13). Emergency laparotomy remains the preferred surgical treatment option in hemodynamically unstable patients or when there are signs of hollow organ perforation. Depending on the extent of local and systemic trauma, the treating physician has to decide whether Early Total Care (ETC) and Damage Control Surgery (DCS) principles need to be applied. While ETC has the goal of primary definitive treatment of the injury with immediate restoration of organ structure and function, the DCS strategy in the acute phase is restricted to hemostasis and prevention of secondary damage (e.g., intra-abdominal contamination, development of compartment syndrome, or anastomotic insufficiency), with the aim of minimizing surgical trauma and operating time. Definitive wound treatment follows in the “window of opportunity” around 5 days later, after the patient has been stabilized and the posttraumatic inflammation has receded. Examples of primary care according to DCS principles are application of an external fixator for injuries of the extremities, temporary blind closure of damaged bowel segments, and leaving the abdominal wall open in the context of surgically treated abdominal trauma.

Even in complex injuries of the extremities and the pelvis, use of an external fixator permits rapid, minimally traumatic fracture reposition and subsequent hemostasis with reduction of secondary soft-tissue trauma (*Figure 2*). Comparative studies have shown advantages of management according to DCS principles for both musculoskeletal (14) and abdominal (15) injuries. However, the benefits seem to be limited to the surgical care of patients with risk factors such as hemorrhagic shock, persistent bleeding, severe head injury, coagulopathy, hypothermia, acidosis, and complex injuries that would be extremely time consuming to reconstruct (10).

Because the liver is a large organ in an exposed position, 16% (16) to 25.2% (17) of seriously injured patients have liver lesions. The severity of liver damage has been identified as an important prognostic factor (18–20). In contrast to the limited evaluability of abdominal hollow organs and the pancreas, both sonography and CT provide excellent visualization of the organ and permit assessment of the extent of hepatic trauma. In hemodynamically stable patients, even high-grade liver contusions and lacerations are now treated by nonsurgical means (21). Together with

Figure 2: Temporary management of a pelvic fracture with a supra-acetabular fixator and of an open lower-leg fracture with an external fixator and a vacuum bandage for the accompanying wound

reliable monitoring of the cardiorespiratory status, liver function, and coagulation status, this comprises interventional measures such as angioembolization and endoscopic procedures such as endoscopic retrograde cholangiopancreatography (ERCP). One precondition for safe nonsurgical treatment is the immediate availability of blood products and the possibility of operative intervention if required (11). A recent systematic analysis identified six risk factors for failure of nonsurgical management of blunt hepatic trauma (21):

- Reduced blood pressure
- High requirement for volume replacement or packed red cells
- Peritoneal irritation
- High ISS
- Additional intra-abdominal injuries

Owing to the poor outcome and high mortality when nonsurgical management fails, primary surgical treatment should be considered in patients with these risk factors (22).

While success rates of over 90% have been reported for nonsurgical management of liver injuries, nonsurgical treatment of splenic lesions is afflicted by failure rates of up to 31% (18, 23). Together with the different structural properties of the spleen, the historically determined lower threshold to surgical treatment seems to be a factor in the lower success rate for conservative management of splenic trauma. Severe fractures and disruptions of the pelvic girdle are often associated with injuries to the intra-abdominal (58.9%) and

urogenital organs (46.6%) (24). Moreover, in the presence of severe pelvic trauma one must anticipate hemodynamically relevant bleeding particularly from the presacral venous plexus. Following preclinical stabilization by means of a pelvic belt, compression of unstable pelvic fractures is achieved with an external fixator (*Figure 3*) or a pelvic clamp. Radiological intervention and vascular embolization have become important in the management of persistent bleeding (25). Definitive surgical management of pelvic girdle fractures ensues according to DCS principles following stabilization of the patient.

Structure of the DGU Trauma Network, White Paper, S3 Guideline Multiple Trauma/Serious Injury Management

The DGU founded its Trauma Network Initiative in 2004, thus answering the call for provision of regionally based structures for the management of severely injured patients. With the aim of improving the care of the seriously injured by introducing nationwide standards for staffing, equipment, and organization, as well as linking individual hospitals, the first regional trauma networks were certified in 2009. A total of 615 hospitals are now certified as trauma centers. These trauma centers form 52 certified regional networks (*eFigure*).

Foundation of the DGU Trauma Network was followed in 2006 by publication of the DGU Whitebook Medical Care of the Severely Injured. A revised version of this document was published in 2012 (6). The

Figure 3: Three-dimensional computed tomography rendering of an unstable pelvic fracture (bilateral fracture of anterior pelvic girdle, left-sided fracture of posterior pelvic girdle)

Whitebook contains recommendations on the structure, organization, and equipment of hospitals of various care levels that participate in the Trauma Network. Furthermore, the S3 Guideline Multiple Trauma/Serious Injury Management, originally published in 2011 and revised in 2016, represents the most important element in the current care concept (5).

Rehabilitation in the DGU Trauma Network

Not least owing to its inclusion in the second edition of the Whitebook, the topic of rehabilitation is attracting increasing attention. Because severely injured patients are often young and otherwise healthy, the physical, mental, and socioeconomic consequences may be

drastic (26, 27). To improve cooperation between acute hospitals and rehabilitation facilities, the DGU and the German Insurance Association (*Gesamtverband der Versicherer*, GDV) combined to initiate the project “Postacute Rehabilitation after Severe Trauma”.

Conflict of interest statement

The authors declare that no conflict of interest exists.

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KEY MESSAGES

- Diagnosis and treatment in the shock room represent the interface between preclinical and clinical care.
- Shock room procedures can be improved by specific training of the staff members involved.
- Surgical hemostasis is recommended in severely injured patients with hemorrhagic shock who do not respond to nonsurgical measures.
- The target systolic blood pressure in severely injured patients with hemorrhagic shock is 80 to 90 mm Hg; in those with severe head injury the systolic blood pressure should be kept >80 mm Hg.
- Liver injuries can be treated conservatively in over 90% of cases, but failure rates of up to 31% have been described for conservative treatment of splenic trauma.

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Supplementary material

eFigure:

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Supplementary material to:

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eFigure: The trauma networks in Germany and neighboring areas (red: supra-regional trauma centers; blue: regional trauma centers; green: local trauma centers)