“Damage Control” in Severely Injured Patients
Why, When, and How?

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The concept of “damage control” is established in the management of severely injured patients. This strategy saves life by deferring repair of anatomic lesions and focusing on restoring the physiology. The “lethal triad” hypothermia, coagulopathy, and acidosis are physiological criteria in the selection of injured patients for “damage control”. Other criteria, such as scoring of injury severity or the time required to accomplish definitive repair, are also useful in determining the need for “damage control”. The staged sequential procedures of “damage control” include, after the selection of patients (stage 1), “damage control surgery” or “damage control orthopedics” (stage 2), resuscitation in the intensive care unit (stage 3), “second-look” operations or scheduled definitive surgery (stage 4), and the secondary reconstructive surgery (stage 5). The concept of “damage control” was carried out in a third of 622 severely injured patients in our division. Although level I evidence is lacking, the incidence of posttraumatic complications and the mortality rate were reduced. However, better understanding of the significance and kinetics of physiological parameters including inflammatory mediators could help to optimize the “damage control” concept concerning the selection of patients and the time points of staged sequential surgery.

Key Words
Trauma · Injury · Host defense response · Primary survey · Life-saving surgery · Emergency room thoracotomy · Damage control · Damage control surgery · Damage control orthopedics · Bail-out procedure · Vacuum-assisted closure · Abdominal compartment syndrome · Systemic inflammatory response syndrome · Mortality

Introduction
The term “damage control” (DC) was coined by the US Navy and refers to keeping afloat a badly damaged ship by procedures to limit flooding, stabilize the vessel, isolate fires and explosions and avoid their spreading [1]. These measures permit damage assessment and gain time to establish plans for definitive salvage. The analogy to the care of a severely injured patient with impending physiological exhaustion is evident and the expression DC was adopted by civilian trauma centers [1, 2].

Battlefield victims with exsanguinating extremity injuries have undergone rapid amputation or deep bleeding wounds have been treated with tamponade packing for hundreds of years. At the beginning of the 20th century, Pringle and Halsted described the digital compression of the portal triad and the use of packing for severe liver injury [3, 4]. These techniques fell out of favor and reappeared with success in the 1970s and 1980s [5–8]. The earlier the liver packing was used the better survival was observed [7]. The concept of abbreviated laparotomy was first described by Stone et al. in 1983 [8]. In this report, abdominal hemorrhage was controlled by tamponade, bowel injuries were resected with oversewing of the bowel ends, noncritical vessels and injured ureters were ligated, and biliopancreatic injuries were drained. The definitive repair of these injuries was carried out after correction of the coagulopathy. The term “damage control” for a successful treatment of penetrating abdominal injuries was popularized by Rondono et al. in 1993 [2]. This strategy has become the
standard of care for abdominal trauma of severely injured patients and was defined as rapid abbreviated laparotomy to stop hemorrhage and peritoneal soiling and staged sequential repair after ongoing resuscitation and recovery from the lethal triad hypothermia, acidosis, and coagulopathy [9].

Based on the DC concept for abdominal injuries, the application of the same principles to the management of multiply injured patients with associated fractures of the long bones and pelvic fractures was named “damage control orthopedics” (DCO) [10]. This term was introduced in the 1990s after description of increased incidence of adult respiratory distress syndrome (ARDS) related to the early definitive stabilization (“early total care” [ETC]) of femoral fractures with reamed intramedullary nailing [11, 12]. These pulmonary complications mostly developed in patients with severe chest injuries and after severe hemorrhagic shock [12].

During the last decade several reviews about the DC concept for abdominal as well as for thoracic and orthopedic injuries were published [1, 10, 11, 13, 14]. The aim of this review article is to summarize some physiological considerations and the work-up for severely injured patients with the integration of the DC concept. Answers to the questions why, when and how DC should be done are given. In addition, some data about the own experiences in DC procedures in severely injured patients are presented.

**Why? – Pathophysiological Considerations for “Damage Control”**

The trauma impact itself determines primary organ or soft-tissue injuries and fractures (first hit, trauma load) with local tissue damages as well as a systemic inflammation with release of pro-inflammatory (“systemic inflammatory response syndrome” [SIRS]) and anti-inflammatory (“compensatory anti-inflammatory response syndrome” [CARS]) cytokines, complement factors, proteins of the contact phase and coagulation systems, acute-phase proteins, neuroendocrine mediators, and an accumulation of immunocompetent cells at the local side of tissue damage (host defense response) [15]. In addition, respiratory distress with hypoxia, uncontrolled hemorrhage with cardiovascular instability, ischemia/reperfusion injuries, avital tissues and contaminations act early as endogenous (antigenic load) second hits. First and second hits can result in the development of the triad hypothermia (core temperature < 35 °C), coagulopathy, and acidosis [1, 16–20]. Each of these life-threatening abnormalities exacerbates the others, contributing to spiraling cycle with cellular hypoxia and failure of the coagulation system. The core temperature of trauma patients decreases rapidly through a prolonged “on-scene time”. This is aggravated by the administration of cold fluids, the presence of extended abdominal or chest wounds, and the removal of clothing in the emergency room [17]. Hypothermia will shift the oxygen dissociation curve to the left, reduces oxygen delivery and the liver’s ability to metabolize citrate and lactate and may decrease the heart rate, cardiac output, or glomerular filtration rate, and increase systemic vascular resistance and arrhythmias [1, 20]. The failure to normalize either an abnormal lactate serum level or base deficit by 48 h after trauma has been correlated with mortalities ranging from 86% to 100% [18].

Furthermore, prolonged surgical interventions with severe tissue damages, evaporative heat loss or blood loss, inadequate or delayed surgical or intensive care after neglected or missed injuries as well as massive transfusions represent exogenous second hits (interventional or surgical load) with exacerbation of the systemic inflammation and lethal triad [15]. Therefore, the philosophy of DC is to abbreviate surgical interventions by deferring repair of anatomic lesions before the development of irreversible physiological endpoints. This operative concept reduces the mortality rate and the incidence of posttraumatic complications (host defense failure) such as sepsis, ARDS, multiple organ dysfunction syndrome (MODS) or failure (MOF) of severely injured patients [1, 10, 11].

**Initial Management – Life-Saving Surgery**

Physicians initially treating injured patients must conduct a systemic work-up. According to the Advanced Trauma Life Support (ATLS®) course patients undergo the primary survey of airway, breathing, circulation, neurologic status and core temperature [21]. Patients with extensive trauma who are unconscious (Glasgow Coma Scale [GCS] < 9 points) or in shock benefit from immediate endotracheal intubation and oxygenation. On rare occasions such as severe maxillofacial injuries or laryngeal fractures, patients require a surgical airway management (cricothyroidotomy or tracheostomy) as life-saving procedure (Figure 1). Simultaneous with airway management, a quick assessment of the patient will determine the degree of shock present. A patient with a