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DAMAGE CONTROL BEYOND THE ABDOMEN (E DEGIANNIS, SECTION EDITOR)

Damage Control Orthopedics

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Abstract

Purpose of Review This review focuses on the concept of damage control orthopedics (DCO), the staged procedure to prevent the multiple injury patients from additional unnecessary trauma by postponable extensive surgery.

Recent Findings The principles of damage control orthopedics are staged procedures and, in the first surgical step, the main principles are to stop the bleeding, to restore perfusion with a limited surgical burden, and to stop the contamination. Criteria for damage control orthopedics correspond those for damage control surgery in general, including hypothermia, evidence for persistent minor perfusion, and coagulation disorders.

Summary Skeletal injuries are very common in multiple injury patients. However, most of these injuries have to be treated surgically, which may be time-consuming, cause further blood loss, increase hypothermia, and also results in an inflammatory response due to the surgical trauma. The concept of damage control orthopedics (DCO) is a staged procedure to prevent the multiple injury patients from additional unnecessary trauma by postponable extensive surgery. The article gives an overview about this concept including the indications and the available evidence.

Keywords Skeletal injury · Orthopedic trauma · Damage control · Damage control surgery

Introduction and Pathophysiological Considerations

Skeletal injuries are very common in multiple injury patients. Only pelvic and femoral fractures may contribute to the hemodynamic instability in these patients. Therefore, musculoskeletal injuries that are generally very common in trauma patients rarely need immediate surgical treatment in sense of a resuscitative procedure.

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However, most of these injuries have to be treated surgically which may be time-consuming, cause further blood loss, increase hypothermia, and also results in an inflammatory response due to the surgical trauma. The concept of damage control orthopedics (DCO) was described already in 1978 German-speaking literature [1]. In 2000, the term "damage control orthopedics" was introduced by Scalea et al. to the international literature [2•].

The principles of damage control orthopedics are more or less the same as for damage control surgery of the abdomen. It is also a staged procedure and, in the first surgical step, the main principles are to stop the bleeding, to restore perfusion with a limited surgical burden, and to stop the contamination. A certain fracture stabilization that allows adequate ICU treatment can be considered as a specific aspect of DCO.

To stop the bleeding in DCO means to reduce and stabilize long bone fracture. Additional surgical procedures in damage control orthopedics are debridement, irrigation, and temporary wound sealing of open fractures—in the sense of stopping the contamination and to revascularizing diminished perfusion by vessel repair or shunting and fasciotomy. Such a staged procedure is definitively indicated if the patient is in extremis. The decision for damage control orthopedics in absolutely unstable patients cannot be proven by randomized trials or similar controlled studies. However, more frequently multiple

trauma patients can be stabilized to a certain degree and the decision for the subsequent surgical strategy needs to be drawn in a more sophisticated manner. These patients were classified as the so called "borderline patients" [3•]. From a pathophysiological point of view, damage control orthopedics has been shown to reduce the inflammatory burden of multiple trauma patients. Pape HC et al. compared the systemic inflammatory response and mediator release after primary musculoskeletal surgery and secondary treatment of long bone fracture after a primary damage control procedure. These studies showed a limited mediator response (e.g., interleukin-6) and a diminished SIRS score if patient were treated primarily with a damage control procedure [4•, 5]. In light of these findings, damage control orthopedics was recommended as a surgical philosophy to prevent overwhelming mediator response after multiple trauma due to a summation of accidental and surgical trauma response. In spite of this pathophysiological consideration, however, the evaluation of the mediator response has no value in clinical decision making or patient selection in clinical routine at the moment. In the context of total trauma load and mediator response, the intramedullary stabilization of femoral fractures is the predominant question. Intramedullary reaming of the femur and to a smaller degree also tibial fractures can cause fat embolism possibly exaggerating a pre-existing pulmonary problem, e.g., based on pulmonary contusions [6], although the fat embolism after intramedullary reaming has been demonstrated in several clinical and experimental studies [7]. However, the actual clinical relevance in terms of ARDS rate, pulmonary complications in general, or mortality could not be shown [8]. On the other hand, reamed nailing of femoral shaft fractures has been showed to be superior to unreamed nailing in terms of bony healing in spite of longer time of surgery and greater blood loss in the reamed group [9]. Therefore, in the whole context of damage control orthopedics, the question of reamed nailing of long bone fractures in multiple injury patients is the key question. Most other musculoskeletal injuries can be either treated in a delayed manner or do not represent a major surgical trauma load and therefore can be treated as an early total care concept if the patient is not in extremis. The only exceptions are pelvic and spinal injuries, which are discussed below in a separate section.

Patient Selection and Evidence for Damage Control Orthopedics

Criteria for damage control orthopedics correspond those for damage control surgery in general, including hypothermia, evidence for persistent minor perfusion, and coagulation disorders [10••]. The unstable patient necessitates these damage control procedures also for musculoskeletal injuries. For patients that can be stabilized to a certain degree, the benefits of a damage control surgery are not completely clear. A systematic review by Rixen et al. revealed no benefits of damage control orthopedics in comparison to early total care in terms of mortality and multiple organ failure [11]. The most recent version of the practice guideline of the Eastern Association for Surgery of Trauma found no difference in mortality comparing early vs. delayed definitive treatment of femoral fractures with a low quality of evidence [12]. To address this relevant open question in trauma surgery, a risk-adapted randomized multicenter trials for this topic was set up [13]. Unfortunately, this trial was terminated due to low patient recruitment [14]. The evaluation of the limited amount of recruited patients (17 early total care vs. 17 with damage control orthopedic surgery) showed no difference in mortality and maximal organ failure score. However, the damage control orthopedics surgery group had a significantly longer ventilation period [15]. In a non-randomized comparison between damage control orthopedics and early total care of femoral fractures, Nicholas et al. found similar results. Both groups did not differ in terms of mortality; however, the early total care group had a significantly shorter ICU stay and ventilation hours [16]. The practice guideline of the German Trauma Society does not give a clear recommendation to the question when early total care or damage control orthopedics should be preferred. Both strategies can be applied and early stabilization of long bone fractures is more frequently recommended. High-level evidence is missing but in case of accompanying severe head injury, persistent hypotension or massive pulmonary contusions damage control orthopedics is a safe strategy. Although bilateral femur fracture may be an indication for a staged surgical procedure in case some severe further injuries. Due to the heterogeneous patient population with these special situations, randomized trials are difficult to perform and a high-level evidence is still missing.

Damage Control Surgery for Spinal and Pelvic Injuries

With the exception of the patient in extremis, surgical stabilization of the spine should be a 1-day surgery. Clearance of the spinal canal should be done within 24 h [17]. There is some evidence that in cervical spine injuries a release of the spinal cord within 8 h has even more benefits in terms of neurological recovery [18], although unstable spinal injuries without proven neurological disorders should be stabilized as 1-day surgery to ease ICU nursing and prevent secondary damage [19, 20, 21••]. In these cases, thoracic and lumbar spine injuries should be stabilized percutaneously dorsally, while cervical spine injuries should be primarily addressed from ventral [22•].

Stabilization of the pelvis is a prerequisite form for bleeding control in this region of the body and may also represent a resuscitative surgical procedure. The external fixator in the supracetabular region is the most frequently used tool. In case

of persistent bleeding, a preperitoneal packing and/or a selective angioembolization can be useful. All further bony reconstructions of the pelvis are commonly associated with a significant blood loss or at least risk for iatrogenic bleeding and may also be time-consuming. Therefore, the fixation of the pelvic ring or the hip joint in multiple trauma patients in general does not represent 1-day surgery. The external fixator or the pelvic C-clamps represent the resuscitative damage control surgery.

Damage Control Orthopedics in the Context of Resources

Damage control orthopedics needs to be discussed also in the context of availability of surgical resources. Damage control surgery in general and especially damage control orthopedics is clearly indicated in military settings. In this context, it is important to mention, that limb injuries represent the majority of all events in the recent military conflicts with involvement of NATO members [23–26]. Limited staff resources and unknown patient load are specificities that military surgeons have to deal with. Therefore, damage control orthopedics is often used as the primary treatment strategy after consideration all factors in military settings [27–30]

The same holds true for civilian mass casualties. This is another clear indication for the application of damage control surgery, in same cases possibly even limited care in the sense of tactical abbreviated surgical care (TASC) [31–33]. However, also in a normal civilian setting, there exists an argument for applying damage control surgery far beyond mediator response or ICU treatment time. Trauma care is not centralized in every health care system and, in many countries, the total load of long bone fractures in multiple trauma patients is decreasing, e.g., due to improved road safety regulations. In addition, working hours in hospital of the individual surgeon also decreased tremendously over the last decades. So, the individual surgeon has only a limited exposure of, for example, femoral shaft fractures. In terms of surgical education, it appears to be recommendable to transfer these procedures to day time working hours. The primary treatment with an external fixator and the secondary intramedullary nailing of femoral or tibial fracture does not have an increased incidence of infection if the conversion to intramedullary osteosynthesis is done within 2 weeks [34]. On the other hand, the rates of surgical complications such as malrotation have been reported with an incidence up to 15% after closed reduction and intramedullary nailing [35]. There are reports that the quality of reduction does not differ between a day time and night time primary treatment of femoral shaft fractures [36]. However, these studies were performed in high volume level-1 trauma centers. Therefore, in terms of patient safety, there are also some aspects that argue for damage control orthopedics especially in hospital settings with limited case load.

Conclusion

Damage control orthopedic surgery is clearly indicated in the unstable patient or for patients in extremis. For all other patients, there does not exist a clear evidence for this surgical strategy. However, relevant adverse effect—may be with the exception of prolonged ventilatory hours—do not exist. Therefore, damage control orthopedics can also be considered as a safe exit strategy in case of limited resources as, e.g., in military settings or civilian mass casualties or even in a low-volume trauma center and a less-experienced surgeon during the night.

Compliance with Ethical Standards

Conflict of Interest The authors declare no conflicts of interest relevant to this manuscript.

Human and Animal Rights and Informed Consent This article does not contain any studies with human or animal subjects performed by any of the authors.

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- • Of importance
- •• Of major importance

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