

FRacture Fixation in Multiple-Trauma- Field of Conflicting Concepts: A Review

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Abstract

The question of whether or not damage control orthopedic surgery is the best strategy to adopt for patients with multiple orthopedic injuries has been extensively discussed over the last few decades. Advances in prehospital care, resuscitation, implants and intensive care medicine have all contributed to the better treatment of the patient in physiological crisis after trauma, who is at risk of multiple-organ dysfunction syndrome and is battling for survival. The strategies evolved from the initial concept "patients are too sick to operate" to early total care (ETC) to damage control orthopedic surgery (DCO) and now individual concept based on anatomical and physiological injury severity. Although these concepts have improved the care of the severely injured and significant decrease of mortality has been noted, fundamental evidence and large prospective randomized multicenter trials are still missing.

The aim of our review was to present both the advantages and disadvantages of ETC and DCO. The most important question of allocation of the right surgical principle (ETC/DCO) to the right patient is also discussed.

Key words: damage control surgery, damage control orthopedics, polytrauma, early total care, complications in polytrauma

ФИКСАЦИЈА НА ФРАКТУРИТЕ ПРИ МУЛТИПЛА ТРАУМА- ПРЕГЛЕД НА КОНФРОНТИРАЧКИТЕ КОНЦЕПТ

Апстракт

Во тек на изминатите децении вредноста на "damage control" концептот во третманот на пациентите со скелетни повреди беше екстензивно проучувана. Напредокот во предхоспиталната грижа, ресусцитацијата, имплантите и интензивното лекување придонесоа во подобрувањето на третманот на пациентите кои се во состојба на физиолошка криза по траума и кај кои постои ризик од развој на синдромот на мултиорганско затајување. Стратегиите за лекување на овие пациенти еволуираа од иницијалниот концепт "early total care" (ETC) во концептот за "damage control orthopedic surgery" (DCO) и конечно во концептот за индивидуален третман врз основа на анатомската и физиолошката тежина на повредите. Иако употребата на овие концепти резултираше со значајно намалување на морталитетот кај тешко повредените, сè уште недостигаат основни научни докази и обемни проспективни рандомизирани мултицентрични студии.

Целта на овој преглед е да се презентираат предностите и недостатоците на ETC и DCO концептите и клучното прашање на примена на соодветниот принцип кај соодветен пациент.

Клучни зборови: "damage control" хирургија, "damage control" ортопедија, политраума, "early total care", компликации при политраума

Introduction

The treatment of the patients who have sustained severe musculoskeletal injuries in polytrauma has been changed tremendously over the past decades. However, trauma is still considered the leading cause of death among those younger than 44 years of age (1). There are reports of significant decrease of the mortality rate following polytrauma over the last decades (2) which is generally the result of the improvements in the critical care of the seriously injured. Extensive research of the pathophysiology of polytrauma improved the surgical management of these patients which resulted in a shift from the classical tri-modal to a bi-modal distribution of a death following severe trauma (2). In other words, the concept for the treatment of polytrauma patients has been changed from the initial one "patients are too ill to operate" to early total care (ETC). The concept of ETC evolved to damage control surgery (DCS) and further on to the newly established individual concept based anatomical and physiological injury severity. Although the development of above mentioned concepts has attributed to the decrease of the mortality in polytrauma management, there is still a lack of fundamental evidence and large prospective randomized multicenter trials.

The aim of our review was to present the advantages, disadvantages and new insights of the concepts of treatment of polytrauma patients and to discuss the appropriate allocation of the right surgical principle to the right patient.

Materials and methods

The present review is based on a search of the literature on damage control and early total care concerning skeletal trauma published in MEDLINE in the period 1980 to December 31, 2014, and the bibliographies of the articles that were retrieved. We searched with the key words damage control surgery, damage control orthopedics, polytrauma, early total care, complications in polytrauma. We considered all displayed reviews, studies, trials and case reports in English. Data were extracted independently by three of the authors and disagreements were resolved consensually.

Historical perspective

The initial step in the development of the scientific concepts for the treatment of the polytrauma patients was the work of Harlan Stone, who described the technique of abdominal packing in coagulopathic bleeding in 1980 (3). Rotondo and Schwab et al. were the first to describe the term "damage control surgery" in 1993 (4). Using this concept in patients with visceral and major vascular abdominal injury, they reported decrease of mortality from 77% to 11% (4). The core of their surgical concept was delayed definitive procedure that was preceded by the initial one consisting of primary bleeding control, resuscitation and stabilization of haemodynamics. Five years later, Moore et al. described the "lethal triad" (5). They emphasized that the coexistence of coagulopathy, metabolic acidosis, hemodynamic instability, infection and pulmonary complications significantly contributed to morbidity and mortality. However, the most crucial event in the development of these concepts was knowledge that the surgical procedure itself represents additional

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injury and activates the immune system of polytrauma patients (6). Nowadays, strong scientific evidence exists that in the polytrauma patients who present with severe haemorrhage, severe soft tissue trauma, severe pelvic disruptions, an over-activated immune response predetermines complications and thus the rate of mortality and morbidity (7, 8, 9, 10). A review of Lasanianos et al. further confirmed the postoperative second-hit in multiple trauma patients related to the presence of the "lethal triad" (11).

The knowledge from visceral surgery was the driving force to the skeletal surgeons worldwide. That is how the idea of damage control orthopedics was born. Five decades ago, most femur fractures were treated with skeletal traction or cast, because the patients were considered "too ill to operate" (12). Two decades later, decreased morbidity and mortality was described following early fracture stabilization, which represented the new concept of early total care (12, 13). However, few years later, the adverse events of ETC were reported (14).

The term Damage control orthopedic surgery (DCO) was introduced by Scalea et al. referring to external fixation of femoral fractures in multiple-trauma (15). Until now, few studies (16, 17, 18) referring to femoral fractures reported decreased mortality following external fixation. However, definitive data are still missing (17).

Knowing that both concepts are joined with their advantages and disadvantages of their own, much of the present scientific research is focused on proper allocation of the right patient to the right therapy.

The principles of Early Total Care in Skeletal Trauma

The core of this concept is represented by immediate definitive osteosynthesis. The study of Seibel et al. showed that application of this principle, resulted in significant decrease of the incidence of pneumonia, ARDS, ventilation time, thrombosis and mortality (19). The same study also showed decreased narcotic requirements, improved pain control and decrease in pulmonary embolism due to early mobilization. Some authors also assess that by following this concept of treatment, the costs were lower (20). However, during the next period, the disadvantages of ETC become apparent. Namely, few studies reported higher blood loss compared to DCO, extensive soft tissue injury with inflammatory response and increased risk of adult respiratory distress syndrome (ARDS) and pulmonary embolism (13, 21). On the other hand, ETC resulted in a lower incidence of pin tract infections, secondary infections and need for additional surgery compared to DCO (22).

Reynolds et al. studied the indications by which a certain patient should be treated according to DCO or ETC principles. Their results showed that the patients with the injury severity score (ISS) less than 18 had benefits from ETC (lower incidence of pulmonary complications) (23). On the other hand, another study demonstrated that even the patients with ISS higher than 17 were successfully treated by nailing following aggressive fluid resuscitation prior to surgery (24). These findings suggested that anatomical injury severity should not be taken into account as a sole indicator while deciding which principle to apply and that the physiological injury severity should also be appreciated.

The Principles of Damage Control Orthopedics

The DCO concept represents avoiding long operation periods and extensive surgical approaches, use of quick and safe surgical procedures, prevention of additional bleeding and

restoration of mechanical stability. DCO techniques are based on temporary intervals via casts for upper extremity, extension or skin traction for lower extremity and external fixation 2/31. If there is concomitant vascular injury present, it should be treated with direct hemorrhage control, ligation, suture, anastomosis or temporary shunting in order to preserve the injured extremity (25). The study of Taeger et al. showed that DCO procedures are shorter and with a lower blood loss compared to ETC (26). Two more studies demonstrated postoperative systemic inflammation is also lower in DCO compared to ETC (27, 28). Having on mind these facts, it is clear that multiple-trauma patients benefit from DCO protocols by avoiding the second-hit phenomenon that can induce endothelial dysfunction and multiple-organ failure. Thus, DCO is recommended in the cases of high injury severity, severe thoracic, pelvic and traumatic brain injury. Namely, the study of Morshed et al. (29) analyzed the patients that sustained combined musculoskeletal and abdominal injury. Their results showed that in a group of patients with severe abdominal trauma in which successful resuscitation was not achievable, intramedullary nailing of femoral fractures resulted in increased mortality. On the contrary, in those group in which delayed internal fixation of musculoskeletal injuries was performed, better outcome was achieved. The effect of nailing of femoral fractures in patients with severe traumatic brain injury was also a subject of research. At least two studies (14, 30) showed worse results in those in whom early intramedullary nailing was performed.

Relation between immediate surgery following trauma and patophysiological mechanisms induced by the trauma itself

In those polytrauma patients who present with severe haemorrhage, severe soft tissue trauma, severe pelvic disruptions or head trauma (7), clinical studies documented that an over-activated immune response pre-determines these complications (8, 9, 10). Within the first hours, the most important physiologic changes are induced by local and systemic hypoxia (31). Blood loss and tissue damage caused by fractures and soft tissue crush injuries induce generalized hypoxemia in the entire vascular bed of the body (32). Hypoxemia is the leading cause of damage as it causes all endothelial membranes to alter their shape. Subsequently, the circulating immune system, namely the neutrophil and macrophage defense system identify these altered membranes. The first immunologic reaction is the adhesion of the neutrophils to the altered endothelial cell walls. This auto-destructive reaction occurs because of lack of external pathogens that usually are a target for these mediators. Proteolytic enzymes and oxygen radicals are liberated into the bloodstream and aggravate the degree of endothelial damage (33). Circulating neutrophils also adhere directly to tissue damaged from contusions, which may be located in the extremities, the muscles or the lungs. Fracture hematoma is known to produce a manifold increase in cytokines, which may subsequently produce systemic effects (34). Subsequently, the damaged endothelial cell wall, by trying to seal the damaged tissue, induces activation of the coagulatory system. This explains why these patients develop a drop in the platelet count. Further cascade mechanisms, such as the complement system, the prostaglandin system, the specific immune system and others are activated (35). It is considered that surgical operations induce similar changes in the immunologic response to those induced by the trauma. Among these, pro-inflammatory cytokines are the most specific for trauma patients (36, 37). The study of Patrick et al. showed that their levels remain elevated for more than 5 days in those with a high injury-severity score. Even more, it is considered that early elevation of the pro-inflammatory cytokines discriminates patients who later develop organ failure (38).

Cytokines are closely related with the magnitude of the injury and also with the operative procedure (39). The inflammatory response induced by femoral nailing is biochemically

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comparable to that induced by other skeletal procedures (40). In addition to the immune response induced by polytrauma, there is exaggerated inflammatory response in which the duration of the surgery and amount of blood and temperature loss play a role (41, 42, 43, 44, 45). In patients who present with very severe injuries, these factors outweigh the positive effects from the definitive stabilization of fractures (15). Prior to introduction of damage control approach, the most frequent treatment of major fractures in these circumstances was skeletal traction. The advantage of using an external fixator over traction lies in the fact that the fracture is stabilized which allows the patient to move for nursing maneuvers and to sit up in the ICU, which improves pulmonary toilet (46).

Borderline patient: decision making process and early appropriate care (EAC)

The issue of correct and optimal treatment of musculoskeletal injuries in multiple- trauma has been a controversy for 30 years. Patients benefit from early fracture stabilization but the optimal time point and the method are still controversy (13). No uniform algorithm on how to treat extremity fractures in multiple- trauma exists (47). Literature study was performed from 1951 to 2002, and due to insufficient evidence, authors could not make recommendation for ETC or DCO (47). It is clear that from ETC concept that haemodynamically stable patients benefit from early fracture stabilization (48). On the other hand, femoral fracture is a predictor for ARDS and statistically predictive for mortality and pulmonary complications (13, 21). Bilateral femoral fracture is associated with increased risk of systemic complications (13, 21).

The question what is stable or unstable patients arises (48). Pape et al. revealed in a prospective multicentre randomized clinical trial three different patient types (48). Stable patients with ETC (<24 hours after trauma) present shorter ventilation time compared to DCO, but borderline patients had a higher incidence of ARDS in ETC group compared to DCO (48). Borderline patients were defined as presented in Table 1. (49).

Table 1 Borderline patient criteria

Blood pressure 80-100mmHg	Body temperature 33-35°C
Received 2-8 blood units within 2h	Thoracic trauma AIS > 2
Lactate 2.5mmol/dL	Horowitz index 300
Platelets 90-110.000/ml	Abdominal trauma Moore < 3
Fibrinogen 1g/dl	Pelvic type B/C injury (AO classification)
Extremity trauma AIS 2-3	

AIS- abbreviated injury scale

The pre-operative condition of the patient is imperative for the decision- making for the type of initial stabilization (ETC or DCO) in multiple- trauma (48). It is not the concept that every patient with musculoskeletal trauma receives primary definitive osteosynthesis or all patients receive external fixation and secondary definitive osteosynthesis. ETC and DCO today go hand-in-hand. With regard to the advantages of ETC, and in respect of the pathophysiology of multiple- trauma, surgeons understand ETC today as early appropriate

care (EAC) (50). DCO should not be abused in every patient. DCO is a powerful tool to successfully resuscitate hemodynamic unstable, in extremis and severe multiple trauma patients. Before surgical decision- making the trauma surgeon has to estimate the total injury severity, know the patient's physiological status and anatomical injuries. Furthermore, multiple- trauma is a dynamic disease and demands repeated re-evaluation. Haemodynamically stable patients receive ETC, unstable patients DCO. In borderline patients individual decision- making based on the dynamic of patophysiological parameters and response to fluid resuscitation is made. Simultaneous operations in borderline patients can save operation time. Always choose the safest and less invasive surgical procedure that the patient endures. Stabilize the patient and restore physiology on ICU.

Management of multiple- trauma with musculoskeletal injury needs an individual concept for each patient. Therefore, damage control should be considered in the patients as presented in Table 2. (15, 17, 19, 22, 23, 51-57).

Table 2 Criteria for damage control

Age > 65 years	Severe traumatic brain injury (AIS > 3)
Haemodynamics/circulation: blood pressure, heart rate	Multiple penetrating torso trauma
Metabolic criteria: acidosis pH < 7.2, lactate > 2.5mmol/L, base deficit > 8	Thoracic trauma (AIS > 3)
Hypothermia < 35°C	Poor oxygenation/ventilation (Horowitz index < 200)
Mass transfusion requirements > 10 pRBC	Abdominal trauma (AIS > 3, penetrating trauma combined with vascular injury)
Coagulopathy: increased PT, PTT, thrombocytopenia, hypofibrinogenemia	Pelvic disruption
Poor response to fluid resuscitation (< 12h after trauma, lactate/base deficit clearance)	Bilateral femur fractures
Injury severity (ISS > 25)	Operation time > 90min. Borderline patient

pRBC- packed red blood cells; PT- prothrombin; PTT- partial thromboplastin time; ISS- injury severity score; AIS- abbreviated injury scale.

Conclusion

ETC is beneficial in moderate injury severity or responsiveness to fluid resuscitation. The ISS or an isolated injury (severe traumatic brain injury, thoracic trauma) without physiological parameters (lactate, base deficit) is inadequate to safely allocate ETC or DCO in multiple trauma. Furthermore, nailing in thoracic trauma is not generally contraindicated and unreamed nails might be beneficial. ETC in moderate injury severity is economical

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compared to DCO. DCO is a quick procedure for bleeding control and mechanical stability in severe multiple-trauma and is beneficial regarding blood loss, operation time, post-operative inflammation and outcome. Especially patients with severe traumatic brain injury and abdominal injuries benefit from DCO. The post-traumatic inflammatory response is significantly lower in DCO compared with ETC.

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