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Perspective

Damage Control Orthopedics as a Lifesaving Strategy in Polytrauma: Minimizing Physiologic Risk Before Definitive Fixation

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ABSTRACT

Background: Polytrauma is a major cause of early mortality and morbidity and is associated with severe physiological instability and systemic inflammatory responses. Early total care (ETC) has traditionally emphasized early definitive fracture fixation; however, extensive surgery in unstable patients may worsen physiological deterioration through the "second hit" phenomenon. **Objective:** This perspective explores the evolving role of damage control orthopedics (DCO) as a staged surgical strategy in polytrauma management and highlights its importance in reducing physiological deterioration before definitive fixation. **Methods**: A narrative review of the current literature on trauma physiology, surgical timing strategies, and outcomes related to DCO was conducted to summarize emerging evidence in modern trauma care. **Results**: DCO prioritizes rapid hemorrhage control and temporary fracture stabilization while delaying definitive fixation until physiological stability is achieved. This staged approach reduces early surgical stress, limits secondary inflammatory injury, and decreases the risk of complications, such as acute respiratory distress syndrome and multiple organ dysfunction. Clinical indicators, including hemodynamic instability, severe associated injuries, metabolic acidosis, hypothermia, and coagulopathy, support the selective use of DCO in high-risk polytrauma patients. **Conclusion**: Damage control orthopedics represents a physiology-driven strategy that emphasizes appropriate patient selection and surgical timing to improve outcomes in patients with severe polytrauma.

KEYWORDS

Polytrauma, second-hit phenomenon, trauma physiology, physiological deterioration

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INTRODUCTION

Early total care (ETC) has long been considered beneficial for many patients with multiple fractures [1]. However, this approach may be inappropriate and harmful for patients in a severely unstable physiological state [2,3]. Since avoiding all surgical interventions is also unsafe, the concept of damage control orthopedics (DCO) emerged as a middle-ground strategy [4–6]. DCO principles prioritize the rapid stabilization of major skeletal injuries, typically through temporary external fixation instead of immediate definitive management [7,8]. Damage control orthopedics (DCO) is used for polytrauma patients whose physiological reserves are critically impaired [9]. The DCO concept aims to achieve early control of hemorrhage, provisional stabilization of major fractures, and prompt management of soft-tissue injuries while minimizing excessive surgical stress [10]. This philosophy builds on the origins of damage control surgery, which was initially introduced to treat exsanguinating abdominal trauma. Abbreviated laparotomy, packing, and delayed definitive repair have been shown to improve survival in patients with hypothermia, coagulopathy, and acidosis [11,12].

The damage control approach has also shown significant value in cases of polytrauma, especially in addressing the "lethal triad." Preventing further soft tissue damage and minimizing the surgical burden are crucial for reducing secondary physiological decline. The term "damage control," taken from naval terminology, signifies the objective of providing immediate temporary stabilization while ensuring the overall success of both the mission and the patient [13,14]. DCO gained traction in polytrauma involving pelvic or long-bone fractures, where extensive early surgery risked triggering a harmful "second hit" due to a surge in inflammatory and metabolic stress [15,16]. Temporary external fixation is generally preferred as the initial treatment, while conversion to internal fixation is reserved when systemic inflammation, tissue swelling, and hemodynamic instability have improved. These principles are particularly important in military settings, where high-energy limb injuries, limited resources, and challenging surgical environments make external fixation the most practical first-line option [12].

The scope of DCO has expanded beyond femoral fractures to include pelvic disruptions, spinal injuries, and upper-extremity trauma. Hemorrhage remains a leading cause of early mortality and a major driver of systemic inflammatory activation [17]. Although transfusion can be life-saving, it may worsen trauma-induced coagulopathy and trigger electrolyte imbalances and immune system dysregulation, adding to the second-hit phenomenon [18,19]. Even surgical attempts to control bleeding can increase coagulation disturbances and inflammatory responses. Therefore, the primary goal of DCO is to limit surgical interventions to essential life-saving procedures until physiological stability is achieved.

Despite its wide use, the DCO principle is not universally defined or is not consistently applied. Evidence from controlled studies is mixed, and the rate of adoption differs significantly among trauma centers [20]. There are ongoing concerns that applying DCO indiscriminately could lead to unnecessary delays, increased costs, or even harm to patients. DCO represents a systematic approach to managing patients with polytrauma. It involves early surgical intervention as part of the overall resuscitation process. Injuries from trauma, fractures, and soft tissue damage are stabilized to reduce additional physiological stress, allowing for definitive repair once the patient's condition is sufficiently stabilized [20–22]. While this review outlines the evolution of damage control orthopedics, the underlying physiological principles, and the outcomes associated with DCO, the primary aim is to synthesize the emerging evidence supporting DCO as a strategic framework for managing polytrauma. By integrating current clinical data with advances in trauma physiology, this review highlights the rationale for applying staged polytrauma care in patients at risk of secondary physiological deterioration.

PERSPECTIVE

Conceptual overview and evolution of DCO

Damage control orthopedics (DCO) refers to a staged orthopedic management strategy designed to provide rapid, provisional stabilization of major fractures while deferring definitive fixation until the patient's systemic condition permits a safer surgical environment [20,23]. This

approach focuses on reducing the physiological limitations of early surgical intervention using minimally invasive techniques, primarily external fixation, during the initial resuscitation phase. Definitive osteosynthesis is performed only after hemodynamic stability, metabolic normalization, and inflammatory downregulation have been achieved [24]. The development of DCO is rooted in the long-term evolution of surgical trauma. Early in the 20th century, orthopedic surgeons considered patients with severe musculoskeletal trauma "too sick for surgery," and treatment often relied on traction and prolonged immobilization [25,26]. Concerns about fat embolism syndrome and a limited understanding of trauma physiology reinforced this conservative approach. External fixation technology gradually emerged during this period, beginning with Hoffmann's frame in 1938, Anderson's linkage system in the 1940s, and Ilizarov's ring fixator system in the 1950s. However, these innovations were not widely adopted. A major shift occurred in 1958 with the establishment of the *Arbeitsgemeinschaft für Osteosynthesefragen* (AO), which championed early functional restoration and advanced the principles of internal fixation [27].

In the 1970s and 1980s, evidence accumulated demonstrating the benefits of early fixation, especially for femoral fractures, which led to the widespread adoption of early total care (ETC). This pivotal randomized study revealed that delayed fixation was associated with increased rates of adult respiratory distress syndrome, pneumonia, and fat embolism, as well as longer ICU and hospital stays. These findings established the ETC as the leading approach, encouraging definitive fixation within the first 24 hours after injury. However, not all polytrauma patients can tolerate ETC [27,28]. In the early 1990s, reports from Europe and North America highlighted that the most severely injured patients, especially those with significant chest trauma, hemodynamic instability, or high injury severity scores, experienced increased pulmonary complications and systemic deterioration after early intramedullary nailing. These observations suggested that the surgical insult itself contributed to adverse outcomes, prompting a reassessment of timing strategies [27,28].

Advancements in trauma immunology have clarified the relationship between the initial traumatic event ("first hit") and subsequent physiological responses. Severe injuries can trigger a strong systemic inflammatory response, and mild trauma may leave the host immunologically primed and vulnerable to further deterioration from additional procedural stress, known as the "second hit". Surgery performed during this window of heightened vulnerability can precipitate acute lung injury, multiple organ dysfunction, or profound metabolic instability. These insights provide a biological foundation for adopting a staged approach to fracture management [15,16]. The concept of "damage control" has gained traction in abdominal surgery, where laparotomy, rapid hemorrhage control, and delayed reconstruction have improved outcomes in patients with coagulopathy, hypothermia, and acidosis. In 1993, Rotondo formalized the term "damage control surgery", and orthopedic surgeons soon adopted the same principles for musculoskeletal trauma [27,28]. Temporary external fixation of long-bone fractures in multiply injured patients has been increasingly reported, with early series demonstrating reduced physiological deterioration compared with immediate definitive fixation [29].

From these developments, DCO emerged as a structured four-phase strategy: (1) acute life-saving interventions, (2) rapid control of hemorrhage and provisional skeletal stabilization using low-insult techniques, (3) intensive care monitoring and systemic optimization, and (4) delayed definitive osteosynthesis within an appropriate physiological window. This staged sequence balances surgical necessity with biological tolerance, ensuring that fracture stabilization does not exacerbate systemic inflammation or impair organ function [20,23]. DCO represents a critical framework in the management of patients with severe multisystem trauma. Its adoption has led to years of advancements in trauma biomechanics, resuscitation science, and immune-physiology, and it continues to develop as evidence defines the best timing and extent of surgical intervention. DCO principles aim to avoid overwhelming the patient's already stressed physiology. By limiting initial intervention to essential stabilization and deferring complex reconstruction, DCO reduces the likelihood of severe inflammatory escalation and supports safer progression to definitive care. The key differences between the ETC and DCO are summarized in Table 1.

Table 1. Shifting paradigms from ETC to DCO in polytrauma care

	Early Total Care (ETC)	Damage Control Orthopedics (DCO)
Origin	Became standard in the 1970s–1980s after studies supported early definitive fixation	Introduced in the early 1990s for unstable polytrauma patients who deteriorated under ETC
Core Philosophy	– "The patient is too sick not to operate" – Universal early definitive fixation was considered beneficial	– "Limit the second hit" – Staged fixation prioritizing physiologic restoration before definitive fixation
Main Principle	All major fractures are fixed definitively within 24 hours	Fractures are stabilized temporarily and definitively fixed later when physiology improves
Initial Procedure	Intramedullary nailing or plating as the first and final operation	External fixation, splinting, or traction as provisional stabilization
Target Patient Population	Hemodynamically stable and well-resuscitated patients	Unstable, borderline, or physiologically compromised patients
Physiological Impact	High risk of "second hit" in unstable patients due to surgical stress	Reduces inflammatory and metabolic burden by delaying major surgery
Advantages	Faster mobilization and lower complication rates in stable patients	Lower risk of ARDS, MODS, and early mortality in unstable patients
Limitations	High risk of complications in unstable patients: ARDS, MODS, worsening shock, metabolic collapse	Risk of pin-site infection, prolonged hospital stay, delayed functional recovery if misapplied or prolonged excessively
Decision Focus	Based mainly on fracture pattern and surgical feasibility	Based mainly on physiological parameters (lactate, base deficit, coagulopathy)

ARDS: acute respiratory distress syndrome; MODS: multiple organ dysfunction syndrome

Clinical applications and outcomes of DCO

Identifying which polytrauma patients are most likely to benefit from the DCO principle has been essential in refining the concept [30]. Several clinical and biochemical indicators are routinely used to assess overall physiological status. These include systolic blood pressure, core temperature, platelet count, serum lactate level, base deficit, oxygenation indices (PaO_2/FiO_2), urine output, and established trauma scoring systems. As our understanding of postinjury immunology advances, inflammatory markers such as interleukin-6, interleukin-10, and HLA-DR expression have been explored as potential tools for predicting deterioration following trauma and surgery [31].

The variability in individual inflammatory responses and the practical challenges associated with obtaining advanced diagnostic tests mean that patient selection for DCO relies primarily on clinical judgment. After initial resuscitation, trauma patients can generally be classified as stable, at risk, unstable, or in extremis. While definitive fixation is usually safe for stable patients, those in the "borderline" category often experience a decline in their physiological condition. The criteria for identifying these patients have been developed through clinical experience and studies that investigate the early physiological effects of orthopedic surgery [31,32].

A DCO strategy is recommended for patients with borderline conditions who fail to improve with resuscitation and for those who are unstable or in extremis. In these situations, operative steps should be limited to essential measures that reduce immediate threats to life. Temporary stabilization of unstable long bones or pelvic fractures with external fixation helps control hemorrhage, prevents further soft-tissue damage, and facilitates rapid transfer to the intensive care unit [31]. External fixation is a rapid and minimally invasive procedure that imposes little

surgical burden. This approach is effective in mitigating the physiological effects associated with a second hit. Definitive fixation, typically through intramedullary nailing, is postponed until the patient's overall condition has improved significantly. Most evidence indicates that this intervention should take place after the fourth day following the injury. Importantly, DCO is designed for a specific group of high-risk trauma patients, and in many institutions, only a small percentage of polytrauma patients actually qualify for this approach [33].

Given that DCO aims to limit secondary inflammatory damage, it is not surprising that a reduced systemic inflammatory response was observed. Studies comparing early intramedullary nailing with the DCO principle for femoral shaft fractures have shown that immediate nailing increases inflammatory activation. In contrast, patients initially managed with external fixation experienced a more moderate systemic response and reduced organ dysfunction. However, if intramedullary nailing is performed while systemic inflammatory response syndrome (SIRS) is still elevated, patients tend to experience more significant physiological deterioration and higher rates of organ failure [34–36].

The ability of temporary external fixation to prevent unanticipated systemic complications has been well established. A multicenter prospective randomized study by Pape revealed that critically injured patients experienced fewer pulmonary complications when initial stabilization was achieved with external fixation rather than early intramedullary nailing [20]. Although the overall complication rates were comparable, the external fixation cohort had significantly higher injury severity scores, suggesting that DCO was performed in patients at an inherently greater risk. These patients also require longer ventilatory and ICU support, reflecting prolonged physiological recovery despite the need to avoid early high-stress surgery [20,30].

While ethical constraints limit the feasibility of randomized trials in severely injured patients, numerous observational and retrospective studies support the utility of DCO. Temporary external fixation has been associated with reduced operative time, minimal blood loss, and safe conversion to intramedullary nailing without excessive procedure-related complications [37,38]. Longitudinal analyses from Level I trauma centers have demonstrated that the shift from early total care to DCO is accompanied by a substantial decline in multiple organ dysfunction syndrome (MODS) among high-risk patients. Recent research by Caba revealed that performing definitive femoral fixation within the first 12 hours of a patient's admission is associated with the highest mortality rates in patients with multisystem trauma. Conversely, delaying fixation to between 48 and 120 hours significantly reduces the risk of mortality [31].

Lethal triad in polytrauma

Severe multisystem trauma accompanied by major fractures represents one of the most critical conditions encountered in emergency care. Global data from the World Health Organization consistently show that trauma is a leading contributor to early mortality, with many patients succumbing shortly after arrival because of uncontrolled hemorrhage, circulatory collapse, or rapid organ dysfunction [39]. Early surgical management is often necessary; however, extensive initial surgical intervention in physiologically unstable patients may intensify metabolic stress, disrupt homeostasis, and amplify the inflammatory burden, increasing the likelihood of pulmonary complications and subsequent organ failure [40,41]. Damage control orthopedics was introduced as an approach intended to mitigate these risks by stabilizing physiological derangements early, reducing ongoing blood loss, and preventing additional soft-tissue trauma. By addressing critical metabolic instability and limiting the magnitude of the secondary inflammatory response, DCO aims to interrupt the cascade that predisposes patients to irreversible physiological deterioration [42,43].

A central concept in the management of major trauma is the "lethal triad", a combination of hypothermia, coagulopathy, and metabolic acidosis that frequently develops in patients with profound hemorrhage and inadequate perfusion (Figure 1). These three abnormalities are tightly interconnected and reinforce one another, creating a downward physiological spiral that significantly increases the probability of death unless it is identified and corrected promptly [39,42,43]. Hypothermia is the most frequently encountered component of the triad. The loss of thermoregulation occurs rapidly in the presence of hemorrhagic shock, impaired oxygen delivery,

and environmental exposure. Even mild reductions in core temperature impair platelet activity, reduce coagulation enzyme function, diminish cardiac output, and promote dysrhythmia [44–46]. Mortality increases sharply when temperatures fall below 34 °C and approaches 100% below 32 °C. Rapid warming, minimization of exposure, and temperature-preserving devices are therefore essential in early trauma care [44].

Coagulopathy arises from a combination of tissue injury, shock-induced hypoperfusion, the consumption of clotting factors, platelet dysfunction, and dilution due to aggressive crystalloid resuscitation. Trauma-induced coagulopathy may be present at admission and is strongly associated with increased mortality. Modern point-of-care coagulation monitoring, such as rotational thromboelastometry (ROTEM), allows rapid identification of reduced clot strength and early prediction of massive transfusion needs. Contemporary resuscitation emphasizes balanced blood product administration and early antifibrinolytic therapy, such as tranexamic acid, to address hyperfibrinolysis and fibrinogen depletion [47–51].

Metabolic acidosis reflects cellular hypoxia and inadequate perfusion. When oxygen delivery is insufficient, anaerobic metabolism predominates, leading to lactate accumulation and a progressive decline in arterial pH [52]. Severe acidosis further impairs myocardial contractility, decreases cardiac output, and significantly disrupts coagulation factor activity. Correction of intravascular volume loss, restoration of perfusion, and optimization of oxygen transport are central to the reversal of acidosis. Persistent severe acidosis signals ongoing hemorrhage or inadequate resuscitation and is a marker of impending physiological collapse [52–54]. Once hypothermia, coagulopathy, and metabolic acidosis occur, each condition exacerbates the others, leading to a self-perpetuating cycle that is challenging to reverse. Timely recognition of early physiological disturbances and targeted interventions focused on all three components are essential for improving survival rates in patients with life-threatening polytrauma [55].

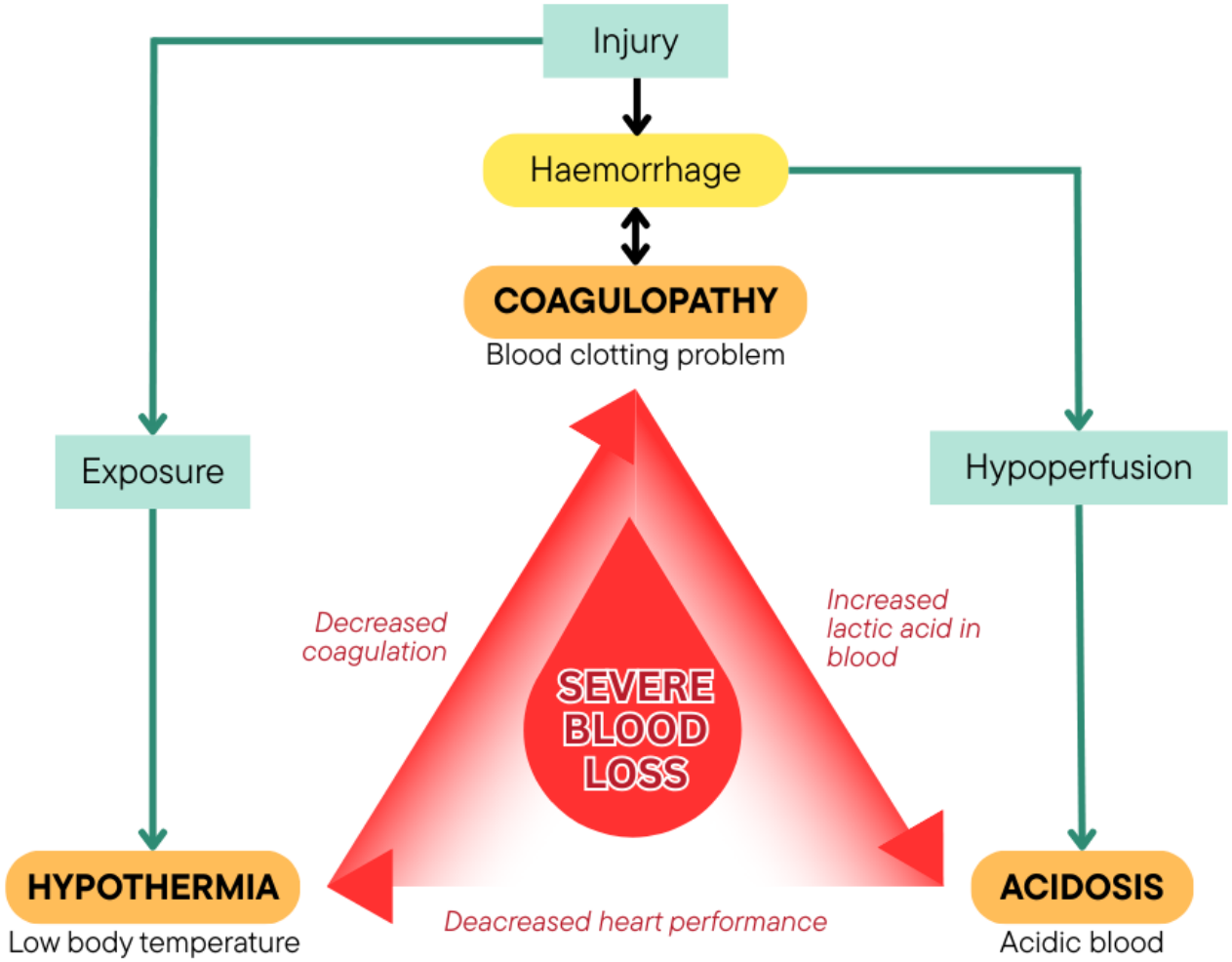


Figure 1. Trauma triad of death.

Principles of DCO in polytrauma care

Modern polytrauma management is guided by the principles of advanced trauma life support (ATLS), emphasizing early identification and treatment of life-threatening conditions through a structured primary survey and concurrent resuscitation [56,57]. Following initial stabilization, patients are physiologically stratified to guide further surgical decision-making. This stratification is critical, as aggressive early definitive fracture fixation in physiologically compromised patients may precipitate an exaggerated systemic inflammatory response or the "second hit" phenomenon. Damage control orthopedics (DCO) was developed to address this risk by prioritizing temporary skeletal stabilization in patients who are borderline, unstable, or in extremis [58]. Clinical decision-making relies primarily on the patient's overall physiological status rather than injury patterns alone. Parameters such as hemodynamic instability, high injury severity scores, severe thoracic or abdominal trauma, hypothermia, metabolic acidosis, coagulopathy, and impaired neurological status have been consistently associated with poor tolerance to prolonged definitive surgical procedures [58,59].

During the acute postinjury inflammatory phase, which typically occurs between days 2 and 5, polytrauma patients are particularly vulnerable to complications, such as acute respiratory distress syndrome (ARDS) and multiple organ dysfunction syndrome (MODS) (Figure 2). Surgical interventions during this period should be restricted to life- or limb-saving procedures. Temporary stabilization through external fixation is crucial for controlling hemorrhage, reducing soft-tissue injury, managing pain, and enabling early intensive care support [60–62].

Damage control orthopedics (DCO) has emerged as a key strategy for selected high-risk patients, prioritizing early life-saving interventions and temporary skeletal stabilization while avoiding excessive surgical stress during the acute postinjury phase. The decision to implement DCO is primarily based on overall physiological status and injury burden rather than fracture pattern alone [10,63]. Several clinical, physiological, and laboratory parameters have been suggested to identify patients who are most likely to benefit from damage control surgery (DCO). These parameters include hemodynamic instability, the severity of injury as measured by the injury severity score (ISS), neurological status, the presence of thoracic or abdominal trauma, metabolic abnormalities, and markers of systemic inflammation. Although inflammatory biomarkers, such as interleukin-6 (IL-6), have been shown to have prognostic value, practical decision-making in acute settings largely relies on clinical evaluation, as laboratory markers may not be immediately available or consistently standardized across institutions [64]. The patient selection criteria for DCO are summarized in Table 2.

Table 2. Patient selection criteria for DCO

	Criteria Suggesting DCO
Injury severity	ISS > 40 without thoracic injury
	ISS > 20 with associated thoracic trauma
Neurological status	GCS ≤ 8
	Head injury with AIS ≥ 3
Hemodynamic status	Hemorrhagic shock (SBP < 90 mmHg)
	Multiple injuries with severe abdominal or pelvic trauma
Musculoskeletal injury pattern	Bilateral femoral fractures
	Unstable pelvic fractures
Thoracic injury	Pulmonary contusions on radiographic imaging
Physiological derangement	Hypothermia < 35 °C
Inflammatory markers	IL-6 > 500 pg/mL
Overall condition	Borderline, unstable, or in-extremis physiological state

GCS: Glasgow Coma Scale; AIS: abbreviated injury scale; IL: Interleukin

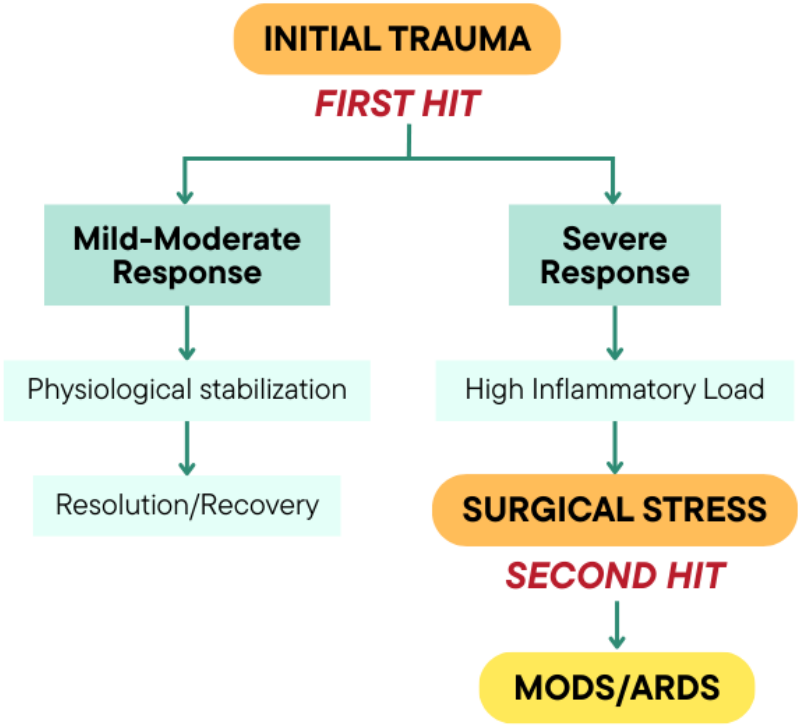


Figure 2. The "second hit" phenomenon in polytrauma.

After initial resuscitation, polytrauma patients can be classified into four physiological categories: stable, borderline (at risk), unstable, and extreme. Early total care is generally considered safe for stable patients. However, those in the borderline category tended to experience physiological deterioration and required ongoing and careful reassessment. In patients who fail to respond adequately to resuscitation, as well as in those classified as unstable or in extremis, the DCO strategy is recommended [59]. Under the DCO framework, all surgical interventions must be rapid, minimally invasive, and life-saving. Temporary stabilization of long bone and pelvic fractures, most commonly achieved through external fixation, plays a crucial role in controlling hemorrhage, limiting additional soft tissue damage, reducing pain, and facilitating early transfer to the intensive care unit (ICU) for advanced organ support. External fixation is preferred because it can be performed quickly with minimal physiological impact, thereby reducing the risk of exacerbating inflammatory cascades [10,64].

The timing of definitive fracture fixation is a critical component of DCO (Figure 3). Patients with polytrauma are particularly vulnerable during the acute inflammatory window, typically occurring between 2-5 days post-injury, when inflammatory mediator peak and tissue edema is pronounced. Definitive orthopedic procedures performed during this period have been associated with a heightened inflammatory response and an increased incidence of organ failure. Only conditions that are immediately life- or limb-threatening should be addressed surgically during this phase [4,8,21]. These include unstable pelvic fractures, compartment syndrome, fractures with vascular compromise, unreduced dislocations, traumatic amputations, unstable spinal injuries, cauda equina syndrome, and open fractures.

Once physiological stabilization is achieved and inflammatory markers begin to normalize, a staged transition to definitive management can occur [64]. In general, the definitive fixation of pelvic fractures is delayed for approximately 7–10 days, femoral shaft fractures are converted from external fixation to intramedullary nailing within three weeks, and tibial fractures undergo definitive fixation after 7–10 days, provided that the patient's condition allows. Evidence suggests that proceeding with definitive stabilization after the fourth postinjury day is associated with improved outcomes and reduced systemic complications [4,30,65]. The DCO procedure is a focused, physiology-driven approach that prioritizes the urgent stabilization of fractures while also aiming to minimize secondary inflammatory damage. When used with carefully selected patients, DCO has demonstrated benefits, such as reducing pulmonary complications, lessening systemic inflammatory responses, and improving survival rates.

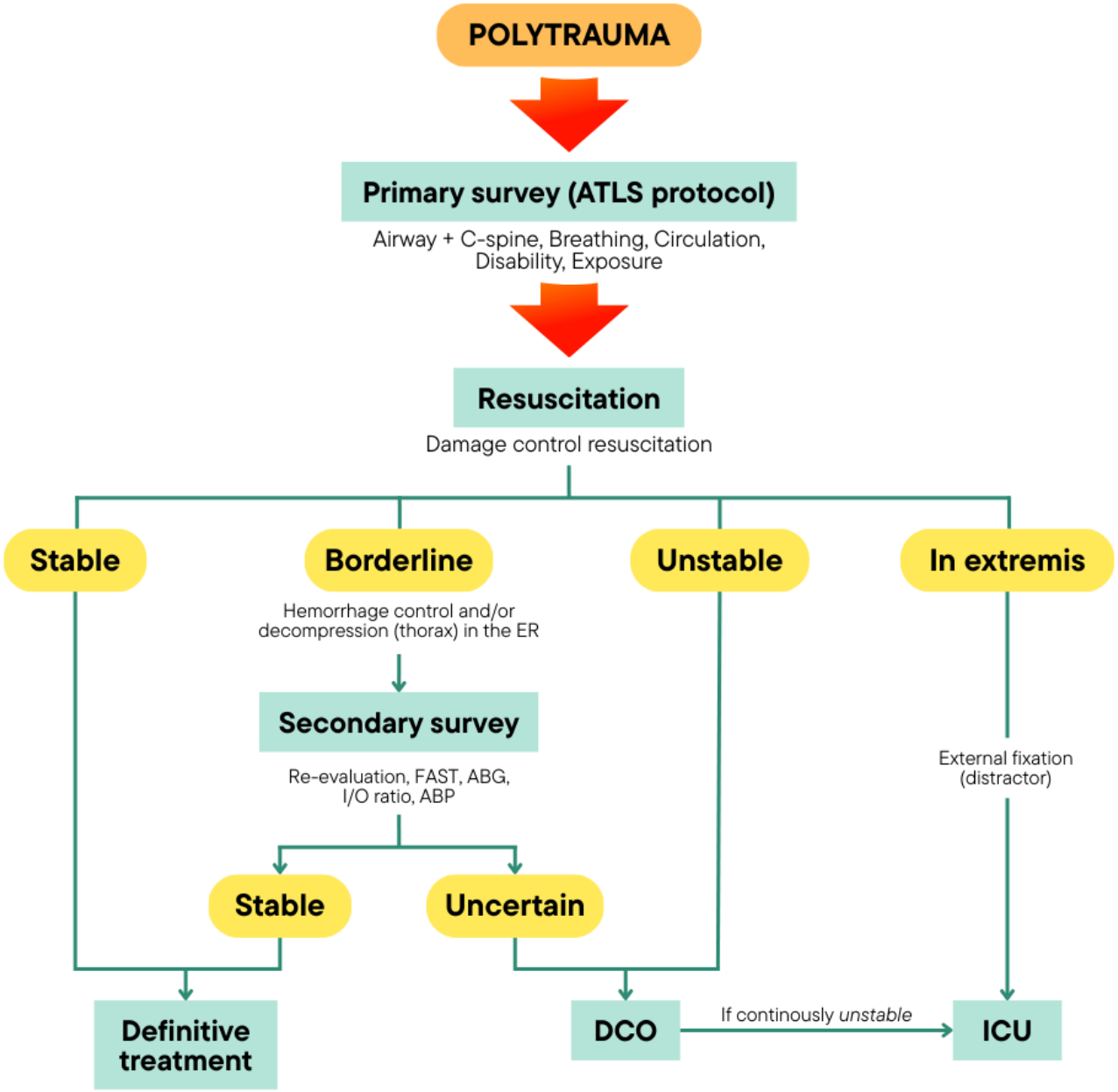


Figure 3. Algorithm for polytrauma management based on ATLS principles and DCO.

Potential risks associated with DCO

The included articles were published in the journals Health STIKES Darul Azhar Batulicin (0.9%, n=1), Journal of Nursing (2.7%, n=3), Comprehensive Health Care (0.9%, n=1), Journal of Nursing and Health Services (IJNHS) (0.9%, n=1), Proceeding National Nursing Seminar (0.9%, n=1), Unimus Journal (0.9%, n=1), Journal of Clinical Medicine (0.9%, n=1), Journal of Clinical Medicine (0.9%, n=1), and Journal of Clinical Medicine (0.9%, n=1).

Damage control orthopedics aims to reduce physiological stress in severely injured patients. However, several limitations must be carefully considered. The staged approach does not entirely prevent an inflammatory surge, as even low-impact procedures, such as external fixation, can trigger the release of proinflammatory cytokines and other mediators. This increased inflammatory response may worsen the body's reaction to trauma and can lead to acute lung injury, impaired blood clotting, infection, or progression to multiple organ dysfunction [41]. Delays in establishing definitive fixation can lead to orthopedic challenges. The prolonged use of external fixation may result in pin-site infections, nonunion, malunion, soft-tissue irritation, or extended immobilization. Reports indicate that certain patient groups, including children or

individuals with multiple severe injuries, may experience a higher risk of mortality, longer hospitalization, and increased resource use when managed with DCO instead of earlier definitive fixation [66,67].

Some clinical scenarios demonstrate an association between DCO and increased early morbidity. Patients with trauma and combined injuries, such as traumatic brain injury and long bone fractures, have higher rates of complications, including respiratory problems, than matched patients treated with a more definitive early strategy do [6]. Interpreting these findings is challenging because DCO is typically reserved for patients experiencing severe physiological instability, which complicates the differentiation between complications due to the intervention and those arising from the underlying severity of the trauma [41].

The absence of universal guidelines introduces additional concerns. Variability in clinical judgment may lead to inappropriate patient selection. Hemodynamically stable patients may receive temporary stabilization despite being suitable candidates for early definitive fixation, which could result in faster recovery and lower complication rates [68]. Conversely, failure to apply DCO in physiologically compromised patients may increase the risk of secondary deterioration [40]. The resource burden associated with DCO is a significant limitation. Patients often require prolonged monitoring in the ICU, delayed definitive procedures, and multiple surgical interventions. These demands increase the overall complexity of care, lengthen hospital stays, and increase institutional costs, particularly in high-volume trauma centers and resource-limited settings [41,69].

CONCLUSIONS

Damage control orthopedics (DCO) has become an essential strategy in the management of patients with severe polytrauma, particularly those with significant physiological instability. Advances in the understanding of trauma physiology, systemic inflammation, and the "first hit–second hit" phenomenon have reshaped surgical decision-making, emphasizing the importance of staged fracture management. DCO prioritizes early life-saving interventions, temporary fracture stabilization, and delayed definitive fixation until physiological recovery is achieved. This approach helps reduce the risk of exacerbating systemic inflammatory responses and decreases the incidence of complications such as acute respiratory distress syndrome (ARDS) and multiple organ dysfunction syndrome (MODS). However, the benefits of DCO depend on appropriate patient selection and careful timing of surgical interventions. Inappropriate application in physiologically stable patients or prolonged reliance on temporary fixation may lead to increased morbidity, extended hospitalization, and increased healthcare costs. Therefore, a physiology-driven approach and continuous reassessment of patient status remain critical in guiding optimal trauma care. Future research should focus on refining patient selection criteria, identifying reliable biomarkers of physiological recovery, and establishing standardized protocols to optimize the timing of definitive fixation and improve outcomes in polytrauma patients.

CONFLICT OF INTEREST

The authors 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.

AUTHOR CONTRIBUTIONS

Conceptualization, investigation, visualization, supervision, writing–original draft, and writing–review and editing: MRAE and TNA.

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DECLARATION OF ARTIFICIAL INTELLIGENCE USE

AI-assisted language tools were used to improve the clarity and structure of the manuscript. All outputs generated with AI support were carefully reviewed by the authors, and all interpretations and conclusions presented in this study are the authors' responsibility.

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