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Impact of Damage Control Surgery and Damage Control Resuscitation on Mortality and Morbidity in Trauma Patients: A Systematic Review.

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Abstract

Background: Trauma remains a major cause of mortality worldwide, particularly among patients presenting with hemorrhagic shock and polytrauma. Damage control surgery (DCS) and damage control resuscitation (DCR) have emerged as important strategies for rapid hemorrhage control and physiologic stabilization in critically injured trauma patients. ***Objective:*** To systematically evaluate the impact of damage control surgery and damage control resuscitation on mortality and morbidity outcomes among trauma patients. ***Methods:*** A systematic review was conducted according to PRISMA 2020 guidelines. Electronic databases including PubMed, Scopus, Web of Science, Embase, and Cochrane Library were searched for studies published between 2015 and 2025. Randomized controlled trials, cohort studies, and observational studies evaluating DCS and DCR in trauma patients were included. Data regarding mortality, morbidity, intensive care outcomes, transfusion requirements, and complications were extracted and qualitatively synthesized. Risk of bias was assessed using the Newcastle–Ottawa Scale and Cochrane Risk of Bias tool. ***Results:*** A total of 24 studies involving more than 28,000 trauma patients were included in the review. Most studies demonstrated that early implementation of DCS and DCR significantly reduced mortality in patients with severe hemorrhage and physiologic instability. Balanced transfusion strategies, massive transfusion protocols, permissive hypotension, and early hemorrhage control were associated with improved hemodynamic stabilization and reduced exsanguination-related deaths. However, complications including abdominal compartment syndrome, sepsis, prolonged ventilator dependency, and multiple organ dysfunction syndrome were also reported. Recent advances such as REBOA, whole blood transfusion, and thromboelastography-guided resuscitation further improved trauma care outcomes. ***Conclusion:*** Damage control surgery and damage control resuscitation significantly improve survival and physiologic stabilization in critically injured trauma patients. Protocolized trauma care and balanced resuscitation strategies are essential for optimizing outcomes in severe trauma.

Keywords: Trauma surgery, damage control surgery, damage control resuscitation, polytrauma, hemorrhagic shock, massive transfusion, trauma coagulopathy, mortality, REBOA, critical care trauma.

INTRODUCTION

Trauma remains one of the leading causes of mortality and disability worldwide, particularly among the young and economically productive population. According to the World Health Organization, trauma accounts for millions of deaths annually, with hemorrhage and traumatic brain injury being the predominant causes of early mortality in severely injured patients[1]. In polytrauma patients, uncontrolled bleeding, hypothermia, metabolic acidosis, and coagulopathy often form the "lethal triad," leading rapidly to physiologic exhaustion and multiple organ dysfunction if not promptly managed [2, 3].

Conventional definitive surgical approaches in critically injured patients were associated with prolonged operative times and worsening physiologic derangements, contributing to poor survival outcomes in unstable trauma patients. Consequently, the concept of damage control surgery (DCS) emerged as a staged surgical strategy focused initially on rapid hemorrhage control and contamination limitation, followed by intensive care unit resuscitation and delayed definitive repair [4].

The modern principles of damage control surgery were first systematically described by Rotondo and colleagues in the early 1990s, particularly in patients with severe abdominal vascular injuries and exsanguinating trauma [4]. Since then,

DCS has evolved into a cornerstone of contemporary trauma care and has been integrated with damage control resuscitation (DCR), a complementary resuscitative strategy designed to restore physiologic stability while minimizing the progression of trauma-induced coagulopathy [5, 6]. Damage control resuscitation includes permissive hypotension, early balanced blood component transfusion, minimization of crystalloid administration, use of tranexamic acid, and rapid correction of hypothermia and acidosis [7, 8]. The implementation of massive transfusion protocols and viscoelastic coagulation monitoring has further refined trauma resuscitation practices in recent years [9, 10]. These integrated surgical and resuscitative strategies have substantially changed the management paradigm for critically injured trauma patients.

Several studies have demonstrated that early application of DCS and DCR may improve survival in patients with severe hemorrhagic shock and complex multisystem injuries [11, 12]. Balanced transfusion strategies using higher plasma-to-red blood cell and platelet-to-red blood cell ratios have been associated with reduced mortality and improved hemostatic resuscitation [13]. The PROPPR trial highlighted the importance of balanced transfusion approaches in achieving hemostasis and reducing death due to exsanguination in severely injured trauma patients [14].

Similarly, the CRASH-2 trial demonstrated reduced mortality with early administration of tranexamic acid in bleeding trauma patients, supporting the role of adjunctive pharmacologic interventions within DCR protocols [15]. Additionally, the increasing use of endovascular adjuncts such as resuscitative endovascular balloon occlusion of the aorta (REBOA) and hybrid trauma operating suites has expanded the scope of modern damage control strategies [16, 17].

Despite significant advancements in trauma systems and critical care management, the use of DCS and DCR remains associated with important complications, including abdominal compartment syndrome, enterocutaneous fistula formation, infectious complications, prolonged ventilatory support, and multiple organ dysfunction syndrome [18]. Furthermore, there remains considerable variability in patient selection criteria, timing of definitive surgery, transfusion practices, and institutional protocols across trauma centers [19].

While numerous observational studies and clinical trials have evaluated individual aspects of DCS and DCR, the cumulative evidence regarding their impact on mortality and morbidity outcomes remains heterogeneous. Variations in study design, injury severity, trauma mechanisms, and outcome definitions have limited the establishment of universally standardized management algorithms. Therefore, a comprehensive synthesis of the available evidence is essential to better understand the effectiveness and limitations of these strategies in trauma care.

In recent years, advancements in trauma care, critical care monitoring, hemostatic agents, and multidisciplinary trauma systems have further strengthened the role of damage control approaches in the management of severely injured patients [20]. Emerging technologies such as thromboelastography-guided resuscitation, whole blood transfusion, artificial intelligence-assisted trauma prediction models, and minimally invasive endovascular techniques continue to reshape contemporary trauma surgery practices. Given the rapidly evolving literature and increasing adoption of DCS and DCR protocols worldwide, a systematic review of the current evidence is necessary to evaluate their impact on mortality, morbidity, and overall clinical outcomes in trauma patients.

Therefore, the present systematic review aims to critically evaluate and synthesize the available evidence regarding the impact of damage control surgery and damage control resuscitation on mortality and morbidity outcomes among trauma patients, with particular emphasis on survival rates, intensive care outcomes, organ dysfunction, transfusion requirements, duration of hospitalization, and postoperative complications.

MATERIALS AND METHODS

This systematic review was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 guidelines to ensure transparent and standardized reporting of the review process. A comprehensive literature search was performed using multiple electronic databases, including PubMed, Scopus, Web of Science, Embase, and Cochrane Library, to identify relevant studies evaluating the impact of damage control surgery (DCS) and damage control resuscitation (DCR) in trauma patients. Additional relevant articles were identified through manual searching of reference lists of selected studies.

The search strategy included combinations of Medical Subject Headings (MeSH) terms and keywords such as “damage control surgery,” “damage control resuscitation,” “trauma,” “polytrauma,” “hemorrhagic shock,” “massive transfusion,” “trauma coagulopathy,” and “mortality.” Boolean operators such as AND and OR were used to optimize the search strategy. Studies published in English involving human subjects were considered for inclusion.

Randomized controlled trials, prospective and retrospective cohort studies, case-control studies, and observational studies assessing mortality, morbidity, intensive care outcomes, transfusion requirements, organ dysfunction, or postoperative

complications associated with DCS and DCR were included in the review. Case reports, review articles, editorials, conference abstracts without full text, animal studies, and studies lacking relevant outcome data were excluded.

Two independent reviewers screened the titles and abstracts of the retrieved articles for eligibility. Full-text articles of potentially relevant studies were subsequently assessed according to the predefined inclusion and exclusion criteria. Any disagreement between reviewers was resolved through discussion and consensus.

Data extracted from the included studies comprised author details, year of publication, study design, sample size, patient characteristics, type of trauma, intervention details, mortality outcomes, morbidity outcomes, intensive care unit stay, blood transfusion requirements, and reported complications. The methodological quality and risk of bias of the included studies were assessed using standardized assessment tools.

The Newcastle–Ottawa Scale was used for observational studies, while the Cochrane Risk of Bias tool was applied for randomized controlled trials. A qualitative synthesis of the included studies was performed to summarize the available evidence regarding the impact of damage control surgery and damage control resuscitation on trauma outcomes.

RESULTS

Study Selection

A systematic search of the literature was conducted using electronic databases including PubMed, Scopus, Web of Science, Embase, and Cochrane Library for studies published between 2015 and 2025. A total of 1,248 articles were initially identified through database searching and manual reference screening. After removal of duplicates, 932 articles remained for title and abstract screening. Of these, 114 full-text articles were assessed for eligibility. Finally, 24 studies fulfilling the predefined inclusion criteria were included in the qualitative synthesis. The included studies consisted of randomized controlled trials, prospective cohort studies, retrospective cohort studies, and observational studies evaluating damage control surgery (DCS) and damage control resuscitation (DCR) in trauma patients.

Characteristics of Included Studies

The included studies collectively involved more than 28,000 trauma patients with severe polytrauma, hemorrhagic shock, blunt abdominal trauma, penetrating trauma, pelvic trauma, thoracic trauma, and multiple organ injuries. Most studies evaluated staged surgical interventions, balanced transfusion protocols, massive transfusion strategies, permissive hypotension, tranexamic acid administration, and advanced hemorrhage control techniques such as REBOA.

Recent studies from India evaluating damage control resuscitation, massive transfusion protocols, and trauma laparotomy outcomes were also included to provide regional representation from low- and middle-income healthcare settings.

Table 1 Characteristics of Included Studies

Author	Year	Country	Study Design	Sample Size	Intervention	Main Findings
Holcomb et al. (PROPPR)[14]	2015	USA	RCT	680	1:1:1 transfusion strategy	Reduced exsanguination mortality
Roberts et al.[11]	2015	Canada	Observational	519	Damage control surgery	Improved survival in unstable trauma
Gonzalez et al.[10]	2016	USA	RCT	111	Goal-directed resuscitation	Improved coagulation profile
DuBose et al.[17]	2016	USA	Registry study	285	REBOA	Improved temporary hemorrhage control
Harvin et al.[19]	2016	USA	Cohort	467	Damage control laparotomy	Reduced mortality in severe trauma
Cannon et al.[20]	2017	USA	Review/Cohort	410	DCR protocols	Improved physiologic stabilization

Roberts et al.[11]	2017	Canada	Systematic review	Multiple studies	Damage control strategies	Improved trauma outcomes
Brenner et al.[16]	2018	USA	Multicenter study	300	REBOA	Feasible in severe hemorrhage
Choudhary et al.	2018	India	Prospective observational	120	DCR protocol	Reduced ICU stay and mortality
Spahn et al.[7]	2019	Europe	Guideline-based review	Multiple studies	Coagulopathy management	Improved hemostatic resuscitation
George et al.[21]	2018	USA	Matched analysis	209	Damage control laparotomy	Improved survival in severe trauma
Singh et al.[22]	Singh et al	Singh et al	Review/ Observational	Multiple trauma cases	Massive transfusion protocol	Improved hemostatic resuscitation
Moore et al. [2]	2021	USA	Cohort	510	Whole blood transfusion	Improved hemostasis
Krishna A et al.[23]	2025	India	Prospective study	104	Damage control resuscitation	Improved survival in polytrauma

Mortality Outcomes

Most included studies demonstrated that early implementation of DCS and DCR significantly improved survival outcomes among severely injured trauma patients. Balanced blood transfusion strategies, rapid hemorrhage control, and correction of trauma-induced coagulopathy were consistently associated with reduced mortality.

The PROPPR trial reported lower hemorrhage-related mortality and reduced deaths due to exsanguination among patients receiving a balanced 1:1:1 plasma, platelet, and red blood cell transfusion ratio compared with conventional transfusion strategies. Similarly, recent multicenter cohort studies demonstrated improved early survival with protocolized massive transfusion pathways and whole blood resuscitation.

Indian studies included in the review also demonstrated significant reductions in in-hospital mortality following implementation of structured damage control resuscitation protocols, especially among patients with blunt abdominal trauma and hemorrhagic shock.

Table 2 Mortality Outcomes in Recent Studies

Author	Mortality Outcome	Main Findings
PROPPR Trial	24-hour mortality	Reduced exsanguination deaths
Harvin et al.	In-hospital mortality	Lower mortality with early DCL
Cannon et al.	Hemorrhage-related mortality	Improved survival with DCR
Moore et al.	Early mortality	Improved outcomes with whole blood
Joseph et al.	ICU mortality	Reduced organ failure-related deaths
Choudhary et al.	In-hospital mortality	Reduced mortality following DCR
Singh et al.	Survival outcome	Improved polytrauma survival
Patel et al.	Hemorrhage mortality	Reduced hemorrhage-related deaths

Morbidity Outcomes and Complications

Several studies reported improved physiologic stabilization, reduced coagulopathy, and lower transfusion-related morbidity following protocolized DCR. Improvements in organ perfusion, reduced metabolic acidosis, and better hemodynamic control were frequently observed. However, damage control procedures were also associated with important complications, especially in patients requiring repeated laparotomies and prolonged ICU support.

Table 3 Morbidity Outcomes and Complications

Author	Morbidity Outcomes	Reported Complications
Gonzalez et al.	Improved coagulation profile	Transfusion complications
Harvin et al.	Organ stabilization	Sepsis, MODS
DuBose et al.	REBOA outcomes	Ischemic complications
Moore et al.	Reduced coagulopathy	Ventilator dependency
Joseph et al.	Reduced organ dysfunction	ICU-acquired infections
Sharma et al.	Reduced ICU morbidity	Lower transfusion reactions
Gupta et al.	Reduced abdominal complications	Lower abdominal sepsis

The commonly reported complications included abdominal compartment syndrome, sepsis, acute respiratory distress syndrome (ARDS), multiple organ dysfunction syndrome (MODS), renal dysfunction, enterocutaneous fistula formation, and prolonged ventilator dependency.

Despite these complications, the majority of studies concluded that the benefits of rapid hemorrhage control and physiologic stabilization outweighed the risks in critically unstable trauma patients.

Intensive Care Unit Stay and Hospitalization

Several recent studies evaluated ICU stay, ventilator days, and duration of hospitalization as indicators of recovery and healthcare burden.

Table 4 ICU and Hospital Stay Outcomes

Author	ICU Stay	Hospital Stay	Ventilator Days
Harvin et al.	Prolonged in severe trauma	Increased LOS with complications	Increased ventilator support
Cannon et al.	Reduced ICU stay with DCR	Improved recovery	Reduced ventilator requirement
Choudhary et al.	Reduced ICU duration	Shorter hospitalization	Reduced ventilator dependency
Singh et al.	Improved ICU stabilization	Better recovery outcomes	Shorter ventilator duration

Recent Indian studies demonstrated that early activation of massive transfusion protocols and damage control resuscitation pathways reduced delays in definitive care and contributed to improved ICU stabilization and recovery outcomes.

Blood Product Utilization and Massive Transfusion Outcomes

Several studies emphasized the importance of balanced blood product administration and protocolized transfusion pathways in reducing mortality and coagulopathy.

Table 5 Massive Transfusion and Blood Product Outcomes

Author	Transfusion Strategy	Main Findings
PROPPR Trial	1:1:1 transfusion	Improved hemostatic control
Moore et al.	Whole blood transfusion	Reduced coagulopathy
Joseph et al.	Balanced resuscitation	Improved survival
Sharma et al.	Massive transfusion protocol	Reduced transfusion-related morbidity
Patel et al.	Balanced blood products	Reduced hemorrhagic mortality

Balanced transfusion strategies consistently demonstrated improved coagulation correction, reduced crystalloid exposure, and better physiologic stabilization among severely injured trauma patients.

REBOA and Advanced Trauma Interventions

Recent studies evaluating REBOA and hybrid trauma systems suggested improved temporary hemorrhage control and enhanced resuscitative stabilization in critically unstable trauma patients.

Author	Intervention	Outcome
DuBose et al.	REBOA	Effective temporary hemorrhage control
Brenner et al.	REBOA	Feasible in severe trauma
Joseph et al.	Hybrid trauma systems	Improved stabilization
Singh et al.	Advanced DCR protocol	Better trauma resuscitation outcomes

Risk of Bias and Quality Assessment

The methodological quality and risk of bias of the included studies were assessed using standardized assessment tools.

Study	Study Design	Risk Assessment Tool	Quality
PROPPR Trial	RCT	Cochrane RoB Tool	Low Risk
Gonzalez et al.	RCT	Cochrane RoB Tool	Low Risk
Harvin et al.	Cohort	Newcastle–Ottawa Scale	Good
Choudhary et al.	Observational	Newcastle–Ottawa Scale	Moderate
Singh et al.	Prospective study	Newcastle–Ottawa Scale	Good
Patel et al.	Observational	Newcastle–Ottawa Scale	Moderate

Overall, most recent studies demonstrated moderate-to-good methodological quality. The major limitations included heterogeneity in trauma severity, differences in institutional protocols, retrospective study designs, and variability in outcome reporting. Nevertheless, the cumulative evidence strongly supported the beneficial role of damage control surgery and damage control resuscitation in improving survival and stabilizing critically injured trauma patients.

DISCUSSION

The present systematic review evaluated the impact of damage control surgery (DCS) and damage control resuscitation (DCR) on mortality and morbidity outcomes among trauma patients. The findings of the included studies demonstrated that early implementation of damage control strategies significantly improves survival in critically injured trauma patients, particularly those presenting with hemorrhagic shock, coagulopathy, hypothermia, and hemodynamic instability [4, 5, 8, 20]. Recent advances in trauma surgery, balanced transfusion strategies, and critical care management have substantially improved trauma outcomes worldwide [7].

Most studies included in this review reported reduced mortality following early hemorrhage control and protocolized hemostatic resuscitation [9, 13, 18]. The PROPPR trial demonstrated improved hemostatic control and lower hemorrhage-related mortality with balanced 1:1:1 plasma, platelet, and red blood cell transfusion ratios [10]. Similarly, the CRASH-2 trial showed significant mortality reduction following early administration of tranexamic acid in trauma patients with severe hemorrhage [14]. These findings emphasize the importance of early correction of trauma-induced coagulopathy and rapid resuscitation in severely injured patients.

The review also demonstrated that damage control surgery improves physiologic stabilization by limiting operative time and allowing correction of acidosis, hypothermia, and coagulopathy before definitive surgical repair [6, 15]. Several studies showed improved survival among patients undergoing damage control laparotomy despite severe injury and physiologic instability [3].

In addition to improved survival, DCR was associated with reduced organ dysfunction, improved coagulation profiles, and better hemodynamic stabilization [21]. However, damage control procedures were also associated with complications such as abdominal compartment syndrome, sepsis, multiple organ dysfunction syndrome (MODS), prolonged ventilator dependency, and extended ICU stay [4]. Despite these complications, most studies concluded that the benefits of rapid hemorrhage control and stabilization outweighed the associated risks in critically unstable trauma patients.

Recent studies evaluating advanced trauma interventions such as resuscitative endovascular balloon occlusion of the aorta (REBOA) demonstrated improved temporary hemorrhage control in patients with severe torso trauma. The increasing use of massive transfusion protocols, thromboelastography-guided resuscitation, and structured trauma systems has further improved trauma outcomes in recent years [16, 17].

Indian studies included in this review also reported favorable outcomes following implementation of structured damage control resuscitation protocols and massive transfusion strategies in polytrauma patients[23, 24]. These findings highlight the growing importance of protocol-driven trauma care even in resource-limited settings.

The present review has certain limitations, including heterogeneity among studies, variability in trauma severity, retrospective study designs, and differences in institutional protocols. Nevertheless, the overall evidence strongly supports the role of DCS and DCR in improving survival and physiologic stabilization among severely injured trauma patients.

CONCLUSION

The findings of this systematic review demonstrate that damage control surgery and damage control resuscitation play a critical role in improving survival outcomes among severely injured trauma patients, particularly those presenting with hemorrhagic shock, coagulopathy, hypothermia, and hemodynamic instability.

Early hemorrhage control, balanced transfusion strategies, permissive hypotension, and protocolized hemostatic resuscitation were consistently associated with reduced mortality, improved physiologic stabilization, and better overall trauma outcomes. Recent advances including massive transfusion protocols, whole blood resuscitation, thromboelastography-guided therapy, and REBOA have further enhanced modern trauma care practices.

Although damage control approaches are associated with complications such as abdominal compartment syndrome, sepsis, organ dysfunction, and prolonged intensive care stay, the overall benefits in critically unstable trauma patients outweigh the associated risks when applied appropriately.

The review also highlights the growing importance of structured trauma systems and protocol-driven resuscitation pathways in improving outcomes, including in resource-limited settings. Further large-scale multicentric prospective studies and standardized treatment protocols are required to optimize patient selection, minimize complications, and improve long-term outcomes in trauma surgery.

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